Vol. XXVI. — No. 10. October 1949.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

Notes on radiant heating,

by H. LENFANT,

Ingénieur principal à la Société Nationale des Chemins de fer belges.

SUMMARY.

FOREWORD.

Before dealing with the principles of radiant heating and its modern applications thereof, we think it would be useful to call to mind the different methods of transmitting heat and to show the part played by such methods in the different heating systems.

We will then proceed to show how the different methods of emitting and utilising calories have evolved : we will endeavour to bring out the advantages and drawbacks of each system of heating.

The transmission of heat.

Heat, which is used in all heating systems, can be transmitted by conductibility, convection, radiation or a mixture.

Conductibility takes place within an object or between two objects in perfect contact by the direct vibration between one molecule and another. In this method of transmission, applicable above all to solids, the relative position of the molecules is not changed.

Transmission by convection takes place between a warm solid object and a cold fluid or between a warm fluid and a cold solid object, and always takes place by contact and movement. The molecules of the fluid are displaced on contact with the surface of the solid object and are heated or cooled thereby.

Transmission by radiation takes place at a distance. The hot object gives out warm rays in all directions, and the heat passes through the air without heating it. Sometimes the heat is accompanied by light.

Transmission by a mixture takes place between two fluids, gases or liquids. This again is a transmission from one molecule to another, but the relative positions of the molecules are altered.

One or several of these methods of transmission can be used, either separately, in turn, or together.

For example an open fire gives heat practically entirely by radiation.

In a boiler, a hot air heater or an ordinary coal stove, the heat passes through the walls in contact with the fire by conductibility. The same process occurs in the case of hot water or steam radiators.

In the boiler itself the water is heated by convection when it comes in contact with the hot wall of the firebox, but a mixture takes place also in the scrubbing which goes on during the circulation. The same thing happens in the case of the hot air heater. In heating the water or air in the above two cases, two methods of heat transmission are used at the same time, i. e. convection and mixed.

The emission of heat by a radiator in central heating takes place by radiation and convection simultaneously. And if the passage of the heat from the water of the radiator to the surrounding air is analysed, three methods of transmission will be found to be involved. First of all conductibility alone, and then convection and radiation simultaneously.

In a hot air heater, fed by hot water or steam, conductibility assures the transmission through the battery, after which the air moved by the fan is heated by convection on contact with the battery and finally transmits its heat by a mixed system to the surrounding air.

In this case three methods of transmission are used in turn.

Such examples can be multiplied, which goes to prove that to heat a place one or several methods of transmission can be used separately, in turn, or simultaneously.

Evolution of methods of transmitting heat.

The first method of heating which man enjoyed, heating by the rays of the sun, is essentially heating by radiation, characterised by the fact that the object emitting the heat is at a very high temperature, though extremely far away. The rays, considering the distance, are parallel. They do not heat the air they pass through. The air is only heated by contact with objects which have absorbed the heat radiated by the sun. For example, in summer when the air temperature close to the ground exceeds 20° C. (63° F) it is well below 0° C. (32° F.) in the upper atmosphere.

This method of heating is enjoyed by lovers of winter sports who find it pleasantly warm although the surrounding air is at a very low temperature.

The open air wood fires of primitive peoples, as well as the open wood fires of byegone days, and even the open coal fires still so popular in Great Britain, emit most of their heat by radiation. It should be noted in passing that the efficiency of such fires is very low, only about 15%.

In fact, until quite recently, the available means of heating were all by radiation. The Roman hypocaust was also a method of heating by radiation. It may be considered as the precursor of modern floor heating, which also is heating by radiation.

Fig. 1 shows how such a method of heating was carried out, combining heating at floor level with the provision of hot water for baths.

Many remains of such installations are to be found, especially in Italy, particularly in the ruins of Pompeii and at Rome in the Lateran Palace.

Figs. 2 and 2' show the remains of similar installations built by the Romans during their occupation of England, at Verulamium, the present day St. Albans, north of London.

Large scale applications based on similar principles have recently been carried out, as we will show in Chapter III.

Fig. 3 shows another example of hypocaust heating discovered at Arles (France) in the building known as the Palace of Constantin. This building is in

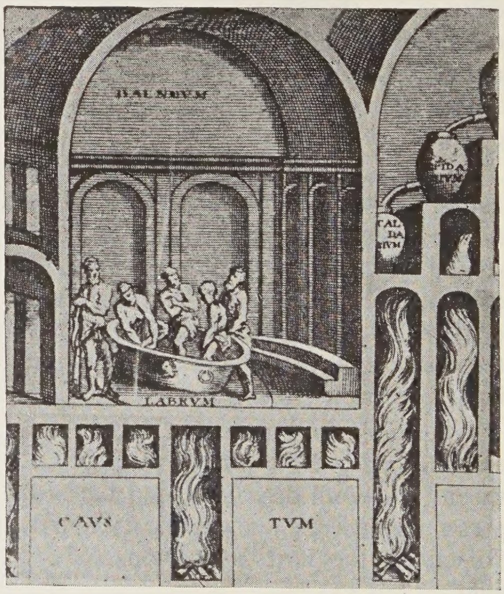


Fig. 1.

reality a bath, now known as Thermes de la Trouille.

The photograph shows the flues under the floor as well as a duct against the wall which formed a heating panel.

Coming to contemporary times, we find metal stoves used in the temperate parts of Europe and pottery stoves in the colder parts. Both types of equipment emit heat through their walls; convection and radiation both occur simultaneously.

A further modification consists of fitting a casing which stops the radiation of heat and allows air to circulate between the heated wall and the case. There the equipment emits its heat by convection.

This evolution from radiation to convection is found in all kinds of heating equipment, whether coal, gas or electricity is used.

In the case of coal, evolution proceeds

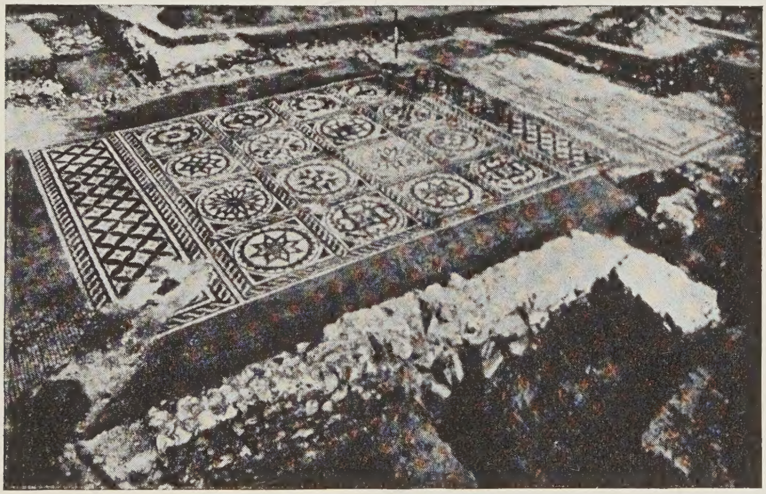


Fig. 2.

from the open fire to the continuously burning type of equipment in which only a small part of the heat is radiated, the outer covering and recuperator with which they are fitted working by convection and giving off most of the heat.

In the more simple types of equipment, which consist of an outer covering of sheet or cast iron, the walls are raised to a very high temperature, often red hot. Heat radiated at a high temperature is unpleasant and dangerous. This is remedied by lining the inside with refractory bricks which prevent the metal from getting red hot. The heat radiated is still at a high temperature, however, and unpleasant.

The first gas stoves consisted of fireclay tubes sometimes fitted with asbestos, which were made incandescent by means of Bunsen burners. The heat was given off by radiation at a high temperature.

Up to date equipment is in the form of central heating radiators, which give off heat by convection.

The first electrical heating equipment from the carbon filament lamp to the parabolic radiator worked essentially by radiation. The latest types are similar to central heating radiators and give off heat by convection. As for the heat accumulating types of equipment, used in Switzerland and other countries where the electricity rates are lower at night, these work entirely by convection.

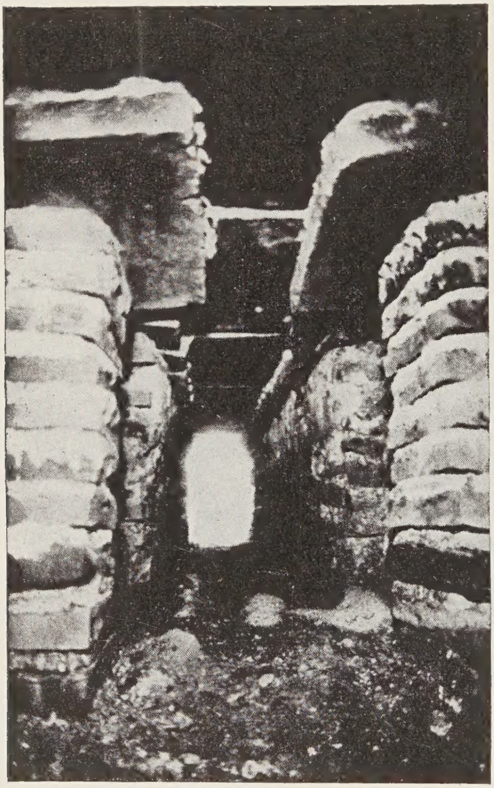


Fig. 2'.

Finally the fuel oil stoves now sold are all convection types of equipment.

Coming to central heating, we find an exception to the order of evolution found in the case of other heating units.

The first type of central heating, by hot air, worked essentially by convection up to the outlets and after that by a mixture. In its primitive form it therefore attained the final stage which heating units have now reached.

And yet it was given up in spite of some very real advantages : it was cheap to install and economical to run. Ventilation was very good. On the other hand, the regulation of the fire and consequently the regulation of the amount of heat emitted was difficult, unless automatic oil fired furnaces or thermostatically controlled coal furnaces, which had not then been perfected, could be used.

Though given up for heating homes, it has come into use once more for heating workshops, thanks to the use of boilers for heating the air fans and pressure ducts. The use of filters, humidificators and thermostats has improved its working. In this improved form, heat is still emitted by convection in the equipment and by a mixture in the shop.

In the case of the two other methods of central heating, heating by steam and heating by hot water, with all the variations found : heating by high pressure steam, expanded steam, steam at low pressure or at a vacuum, hot water heating at low or high pressure, natural or forced circulation, there has been relatively little change in the way the heat is emitted. The equipment has been perfected by the use of smooth or ribbed pipes, radiators and air heaters.

Except in the case of high pressure steam or superheated water, and the use of coils of smooth or ribbed pipes in which case radiation is appreciable, the heat is emitted for the most part or completely by convection.

We have already explained the working of air heaters which only emit heat by convection and mixture.

In the case of radiators, both hot water and steam, heat is emitted above all by convection. Unless one is very close to the radiator, the heat given off is not felt; on the other hand it is only necessary to place one's hand over the radiator to feel very distinctly the heat of the rising current of air heated by convection. In fact it would be more logical to call convectors such apparatus.

We have sketched in very roughly an evolution aiming at doing away with heat radiated at high temperature from surfaces too near the occupants of the room.

However, in spite of the remarkable technical solutions which have been reached, both designers and users are very conscious of the defects of convection. We will endeavour to explain these defects.

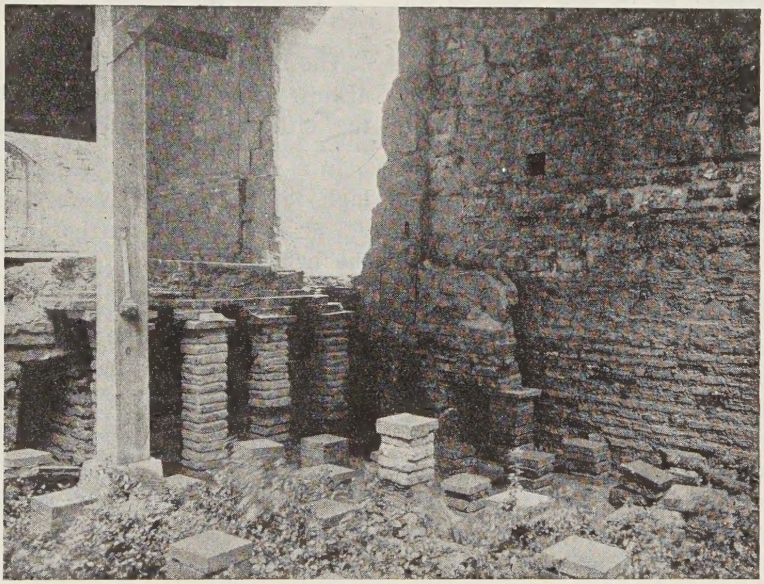


Fig. 3.

Characteristics and defects of convection.

The heating of a private house by hot water, equipped with all the latest improvements, such as automatic oil or coal fired furnaces controlled by thermostats in the rooms, can be run so as to assure a

regular temperature, whatever the variations in the outside temperature. However complete comfort is not achieved in this way. The occupants find it disagreeable to open windows in cold weather. This is because the air of the room is the means by which the heat is transmitted to the bodies of the occupants. In addition it is unpleasant to be too close to an outside wall, as its inner face is affected by the transmission of heat towards the outside. This is because the exchange of heat between the human body and the wall is unbalanced. If there is a great difference in temperature between the body and the wall, the loss of heat from the body by radiation is accelerated. This gives a feeling of cold in spite of the warmth of the room.

Moreover, if the temperature of the air is taken at different levels in the room, it is found to be very unequal and increasing from floor to ceiling level. Distribution at a given horizontal level is also unequal owing to the draughts set up by the air on coming into contact with the radiator.

When heating a large building, such as a block of offices for example, the drawbacks reported above are not eliminated in spite of all the improvements made, such as regulations by zones, automatic regulation by thermostats or variostats. The renewal of the air during office hours often makes it necessary to fit mechanical ventilators, which are costly to operate. Neither the influence of the walls nor the draughts are eliminated within the rooms. Positions near the window, which are the best from the point of view of natural light, are the least comfortable owing to the effects of the cold walls.

In the industrial field, the heating of working shops and in particular of large ones gives rise to great difficulties.

Static heating can only be used in small shops of limited height.

Certain concrete examples showing the defects of convection.

The author of this article has been up against several problems which confirm the criticisms expressed above.

In a narrow shop which was not very high, ribbed pipes were sited about 2.5 m. (8'2 ½") from the ground above the benches.

Radiation from the pipes, which were steam heated, was too near the heads of the workers, so the pipes had to be raised. This did away with the disagreeable effects of the radiation; on the other hand the efficiency of the equipment was also affected, as convection did not take place so easily.

At a time when the use of air heaters was not yet developed, the heating of a boiler shed 25 m. (82' 1/4") wide and 15 m. (49' 2 ½") high was carried out by means of groups of pipes arranged horizontally at two levels. The desired temperature at working level was achieved, but the driver of the travelling crane had to work in too high a temperature. In the centre of the shop the down draughts of cold air could be clearly perceived.

A shop communicating with other shops had to be heated. The temperature in this shop had to be high enough to make it possible to equip railway wagons with air brakes during the winter. An important

part of the work had to be carried out in the pits under the wagons.

A relatively large number of hot air heaters were fitted in the working area. The temperature was raised appreciably by this means, but a large part of the heat was dispersed throughout the adjacent shops.

In a diesel railcar shed, heating was necessary to prevent the radiators freezing and to keep the oil sufficiently fluid. On the other hand, the emission of smoke when the railcars were started up made ventilation important. Heating by hot air heaters proved to be inadequate.

In all the examples quoted, convection heating was involved, and the air, the means through which the heat was diffused, dispersed it in a manner that was difficult to control.

In the last example, the problem of heating the air as an agent for transmitting heat was incompatible with the problem of ventilation. The same difficulty arises when trying to heat a locomotive shed, either by static surfaces or hot air heaters.

In such applications convection heating is defective or inadequate and costly. In all these cases the problem could have been solved much more satisfactorily as far as the workers were concerned, and more economically, if radiant heating could have been used in any of the forms now available.

Conclusions to be drawn from this preliminary report.

We have seen that radiation from equipment raised to a high temperature and sited near the occupants has been rejected in every case, and this has led invariably to convection equipment being favoured.

We then saw that the convection heating solutions adopted, in spite of the improvements made to them, were far from satisfactory.

We will endeavour to explain the reasons for this failure, and this will show why radiant heating is justified in its up to date forms.

The idea of comfort.

The human body is an organism whose essential characteristic is the physiological necessity of maintaining a constant inner temperature of about 37° C. (98.6° F.).

The chemical reactions which take place in the lungs between the oxygen in the air and the carbon and hydrogen in the blood are a continuous source of heat production. Part of this heat is used by being transformed into energy by the interior activities of the body, such as circulation, respiration, etc.; another part is transformed into useful outside work; whilst yet another is dispersed in the form of actual heat by the phenomena of respiration, transpiration and losses from the outside of the body.

Experience shows that when the body is at rest, the loss of internal heat is accompanied by a feeling of well-being when the surrounding temperature is about 18° C. (64.4° F.).

When the temperature falls below 18°, a naked body has to take steps to prevent an undue loss of heat.

To do this it unconsciously lowers its superficial temperature by the contraction of the blood vessels. In addition it meets the increase in the loss of heat by increas-

ing its internal production of heat; this is the sensation of cold.

On the other hand, if the temperature is more than 18°C., the body has to make good an insufficient loss of heat; to do so, the temperature of the skin is increased and evaporation through the skin; this is the sensation of heat.

These elementary considerations show that the more active a man is, the more heat there is to dissipate. This means that the comfortable temperature falls in terms of the activity of the work, and may vary between 18° and 8° C. (64.4° and 46.4° F.) according to the activity of the body.

An adult when immobile releases an average of 90 calories (357 B.T.U.) an hour in a temperature of 17° C. (62.6° F.). A manual worker releases 160 calories in a temperature of 12° C. (53.6° F.).

This emission of heat from the human body is divided up as follows :

Losses through radiation	50 %
Losses through convection	25 %
Evaporation from the skin	16 %
Evaporation from the lungs . . .	9 %

Exteriorly the human body may be compared to a hot, humid object; it loses its heat through radiation and convection on the one hand and through evaporation on the other.

It can therefore be seen that different conditions of heat and humidity may involve the same calorific losses, and consequently give the same impression of heat.

Research work carried out in America on equivalent atmospheres, took into account the dry temperature, the humid temperature, and the movement of the air. They made it possible to establish standards for the calculation of the effective temperature and the determination of the zone of comfort.

In France, following researches, apart from the characteristics of the air, it was found necessary to take into account the temperature of the walls of rooms; this in fact plays an important part in the feeling of heat, owing to the fact that there is a permanent exchange of heat between the human body and these walls.

This gave rise to the idea that by heating the walls it would be possible to maintain the same sensation of heat whilst reducing the temperature of the air.

In addition, if the ground is heated to a higher temperature than the air, the sensation of heat is increased owing to the fact that the loss of heat from the body through the feet is diminished.

The impression of heat given felt in a room depends therefore on :

1. the dry temperature of the air;
2. the degree of humidity of this air;
3. the relative speed of the atmosphere and the body;
4. the average temperature of the walls;
5. the temperature of the ground.

In this way a given sensation of heat or coldness can be given by different methods, by acting on the temperature of the air, its movement, and its humidity, as well as on the temperature of the walls.

To compare these different atmospheres, they are given a characteristic known as « resultant temperature », it being understood that equivalent atmospheres have the same resulting temperature.

To define it : the resultant temperature of an enclosure is the temperature of an equivalent enclosure in which the air is saturated at rest and the walls are at the same temperature as this air. In this case, the resultant temperature is that of the ordinary dry thermometer.

The resultant temperature characterises the exchange of heat between the human body and the surrounding air, and methodical researches have proved that the different physiological functions (metabolism, respiration, release of carbon acid, circulation) are appreciably the same for a same resultant temperature.

It has also been found that an increase in the temperature of the walls by 1° will make good a drop of 1.1° in the dry temperature.

What is the optimum resultant temperature for the body?

Obviously it depends on the thickness of clothing and activity of the individual.

In winter it varies from 16 to 19° C. (60.8° to 66.2° F.) for sedentary individuals and 8 to 12° C. (46.4° to 53.6° F.) for very active individuals.

The main question is to ascertain the best temperature for the air that is breathed in, the body being in a comfortable atmosphere.

At the present time it is agreed that the temperature of the air should be rather below 18° C. (64.4° F.) in order to assure efficient cooling of the lungs. Under these conditions, to give the same degree of comfort, i. e. the same feeling of well-being the dry temperature of the air has to be lowered whilst raising at the same time the temperature of the walls.

Let us briefly consider how the emission of heat by the human body can be influenced by the surrounding atmospheric conditions.

Heat due to respiration is accompanied by steam. It is clear that the temperature of the air and its degree of humidity have a direct effect on the phenomenon of respiration. If the air is too hot and dry, like that produced by hot air heaters, the mucous tissues are dried up, the throat is irritated and the proper working of the lungs impeded. On the other hand, if the air is too damp, hot or cold, the working of the lungs is also impeded and an impression of suffocation given; this occurs in hot weather before storms, and in cold weather when it is foggy.

For this reason, good ventilation is essential in places where it is steamy, such as baths, wash-houses, and certain shops.

The elimination of heat by transpiration is affected both by the temperature of the air and its degree of humidity, as well as its speed of movement. During times of storm or fog, as mentioned above, transpiration takes place with difficulty, and clothing becomes damp.

The body either when dry, or especially when transpiring, feels cold the moment it comes in contact with an air draught. This phenomenon explains in our opinion the dislike of workers for heating by hot air heaters. Manual work is always accompanied by transpiration to a greater or lesser degree according to the activity of the worker, and the draughts caused by the hot air heaters are felt more by the workers than by the technical expert in charge of the heating tests. As far as he is concerned the stipulated temperatures have been reached and the problem is solved. The workers do not think so. To

be able to form a proper judgment on the matter, the technical expert should be clothed and work under the same conditions as the men.

Loss of heat by convection is influenced by the temperature of the air and its speed. A current of air will speed up the loss and give an impression of cold whether the body is dry or transpiring.

Finally, loss of heat by radiation, which accounts for the greatest part of such losses, about 50 %, is only affected by the temperature of the walls which can or cannot absorb the heat. If the walls are at a high temperature, the body absorbs the radiation from them. If on the contrary the walls are cold, the heat radiated by the body is absorbed by them. If the walls are too cold, radiation from the body is speeded up, which gives a definite impression of cold.

Now calculations have shown that the walls of rooms heated by convection are always appreciably colder than the air in the room, and consequently than the body. One has only to remember the frost on the windows and the condensation on the walls in spite of the room being heated at a normal temperature.

To bring out the contrast between heating by convection and heating by radiation at low temperature, let us consider a room heated by radiators during the winter at a temperature of 18° C. (64.4° F.), the walls of which have a temperature of 10° C. (50° F.).

The occupant, whose outer temperature can be taken as 27° C. (80.6° F.) radiates heat towards the walls and feels cold.

If the air is dried up by its contact with the radiator through which the volume of air in the room passes 4 to 6 times an hour, this will cause cooling, owing to the evaporation of the superficial moisture of the skin.

Experiments have been carried out in Canada : when the outside temperature remained at 19° and 20° below freezing point during the long winter days, the outer walls and windows were at so low a temperature that the temperature in the room heated by radiators had to be 27° to 30° C. (80.6° to 86° F.), otherwise the occupants were shivering, such was the radiation from the human body towards the cold walls.

In our temperate climate, the variation between the temperature of the air and that of the walls is obviously less marked, but it does exist, and as the loss of heat from the body takes place above all by radiation, it is understandable that this directly affects the feeling of comfort.

In a room heated by radiation, the walls are heated directly by radiation. The variation between the temperature of the body and that of the walls is consequently reduced. As a result the exchange of heat between the body and the walls is also reduced. This results in a greater feeling of comfort than in the case of heating by convection.

The above report shows that the problem of heating is not so much that of heating the body which is itself a heat producing center that has to expel part of its heat, than that of limiting its loss of heat, in other words it is the problem of allowing the body to cool off under the best conditions.

We have seen that heating by convection only affects the temperature of the air.

It does not regulate either the humidity or speed of movement of the air; it does

not regulate, at least not to any appreciable extent, the temperature of the walls.

Air conditioning, which is made necessary by manufacturing conditions in certain industries, such as the textile industry, or the result of the standard of comfort demanded in certain countries such as the United States, solves the heating problem to a much greater extent and the ventilation problem at the same time, but it does not regulate the temperature of the walls.

However air conditioning is expensive, both from the point of view of first cost and operating costs. The technicians only adopt it when it is absolutely necessary.

We have found that this development has been relatively slow in our temperate climate.

To sum up, it is because of the deficiencies of heating by convection and the cost of air conditioning that new methods of radiant heating have been so welcomed by the technical experts. They have found therein, in its up-to-date forms, solutions to most of the problems which so far have only been partly solved.

Principles of heat radiation.

The study of heat radiation is properly speaking part of the optical field. The identity of radiated heat and light was proved by the experiments of Masson and Jamain.

These physicists showed that if a simple ray of red light undergoes an absorption of 25 % when passing over a given surface, its heat content was diminished to the same extent.

In the same way, if a ray of light falls on a glass surface and the quantities of light and heat reflected thereby are studied, both quantities will vary in exactly the same way.

The light and heat of the sun which reach right down to the earth without heating space on the way, obey the same physical laws.

The least refrangible rays of the spectrum, the red rays, are warm and light. If they are reflected or refracted, they will always effect a raising of the thermometer. A ray of red light is therefore always accompanied by an invisible ray of heat.

If a spectrum is formed by means of a lens and prism, the heat rays are refracted exactly like the light rays, according to the principles of optics. There is no heating with the violet, blue and green rays, very little with the yellow and orange, but more and more as red is reached. The greatest point of heating lies outside the spectrum : it is due to the infra-red rays which are less refrangible than the red.

To sum up, it can be stated that the calorific spectrum encroaches upon he light spectrum from the yellow and orange onwards and stretches beyond the red.

When the heat rays encounter a body, part of the heat penetrates this body; this is the absorbant power.

Part is reflected according to the laws of light; this is the reflective power.

A third part is diffused in all directions like light on a mat surface : this is the diffusive power.

Finally a fourth part penetrates certain bodies without heating them : this is the diathermic power.

These four powers vary according to

the nature of the body receiving the rays, the emissive power of the radiating body and the wave lengths of the rays emitted. The wave length depends upon the temperature of the body emitting them. For example ordinary glass lets the short-wave heat rays of the sun pass very well, whereas it absorbs and reflects long wave heat rays, i. e. those emitted by a surface whose temperature is below 70° C. (158° F.).

The heat reflected depends upon the nature of the object which receives the rays, the angle at which they fall, and the wave length.

As for the diathermic power, this is characterised by the fact that pure air lets heat rays pass through it practically without absorbing them. The air is not heated by the effects of radiation.

It can therefore be seen that owing to these physical properties of radiated heat, it is possible to heat the walls of a room as well as all the objects within it without thereby increasing the temperature of the air appreciably. This makes it possible to create a comfortable atmosphere in which the human body is thermically in equilibrium according to its activity, and in which the air is neither overheated nor desiccated, nor draughts caused by the effects of convection.

It also can be seen that owing to the possibility of controlling the direction of the heat rays and limiting them to a given room, it is possible to heat certain parts of large rooms without having to heat them throughout.

Methods of realisation.

Making an exception of direct heating by coal fires, all the sources of heat used in convection heating are also to be found with radiant heating.

1° Low pressure hot water circulated by a pump;

2° High pressure steam and superheated water;

3° Hot air;

4° Gas;

5° Electricity.

We will consider the different applications in turn.

I. HEATING BY LOW PRESSURE HOT WATER CIRCULATED BY A PUMP.

With such installations, low temperature radiant panels are used.

The credit for the first trials and for perfecting the methods used are due to Professor A. H. BARKER and Richard CRITTALL, who carried out such installations in Great Britain as early as 1910. The firm of Richard Crittall & Company whose headquarters are in London, has associated companies throughout the world. It has granted licences to work its patents to various foreign firms. They are based on the use of steel pipes.

The success of the first installations carried out in England aroused the interest of engineers in the United States. As far back as 1910 Professor Theodore CRANE of Yale Arts Faculty investigated the matter and carried out the first installations in America.

While the technique invented in England using steel pipes for coils was in progress, another system using copper pipes was started in the U. S. A.

From the beginning the heating panels were sited in the ceiling, in the walls or in the floor.

These panels consist of coils of 1/2" or 3/4" steel pipes fitted in the walls. Water is passed through them, by means of a pump, at a temperature of not more than 50° C. (122° F.).

These pipes, spaced 10 to 20 cm. (4" to 7 7/8") from centre to centre, heat radiator in a convection type heating system.

Thanks to the siting of the coils and the fact that each coil is a separate unit, it is possible to adapt the emission of heat to actual requirements, i. e. the general temperature can be regulated by regulating

Fig. 4.

the whole wall by conductivity, so that the surface of the wall is warmed to a temperature appreciably below that of the water. The whole surface of the wall thus becomes a large heating area which gives off radiant heat at a low temperature.

The coils are arranged according to the way the room loses its heat. They may be partly concentrated near those walls from which the loss of heat is the greatest, for example windows and outside walls.

Each coil or group of coils is controlled by a tap and can be cut out, just like a

the temperature of the water, and the heat can be concentrated where it is required by cutting out certain coils. This latter method is employed in large rooms.

Whether ceiling, floor or wall, be used for the heating, the phenomena entailed are the same. The hot rays, at a low temperature, pass through the air without heating it, but the human body, the walls of the room and the furniture absorb part of it and reflect part of it, in variable proportions according to the colour and nature of their surface.

As the air is no more the vehicle through

which the heat passes, as in the case of convection, the air can be renewed without any appreciable loss of heat that will affect the occupants. It is therefore possible in cold weather to obtain a feeling of comfort in a room heated by radiant heat even when the windows are open, so long as there are no direct draughts. An illustration in support of this fact can be found in the many schools, particularly in Great Britain, where class rooms are fitted with walls which can be completely opened to the outside air (Fig. 4).

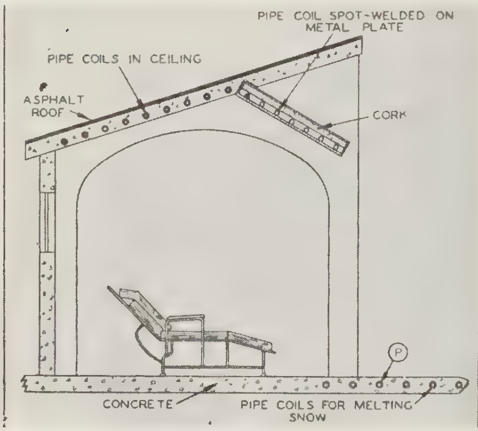


Fig. 5.

Fig 5 shows another application, the heating of a gallery always open to the outside air, such as is met with in hospitals and sanatoriums.

The outer pipe coils not only heat the gallery but also melt the snow.

For the same reason that air is not the medium of heat, the distribution of the temperature at various levels is more constant than in the case of convection heating. This property will be illustrated by graphs during the report.

The above are the essential character-

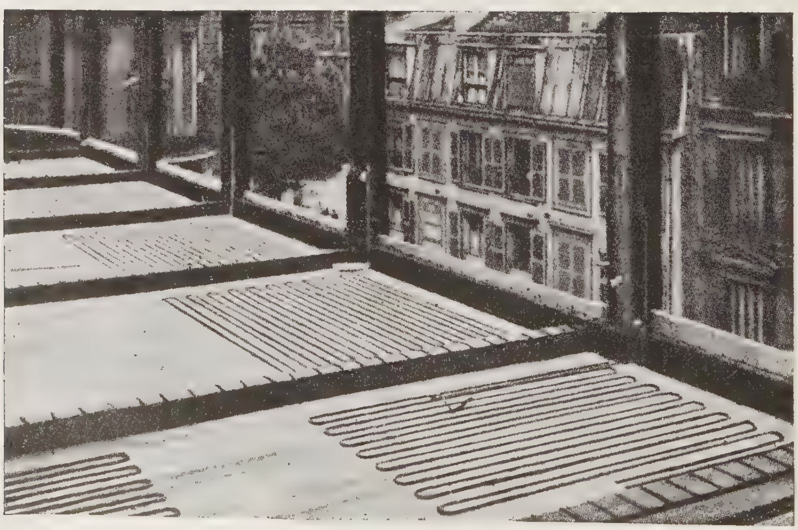


Fig. 6.

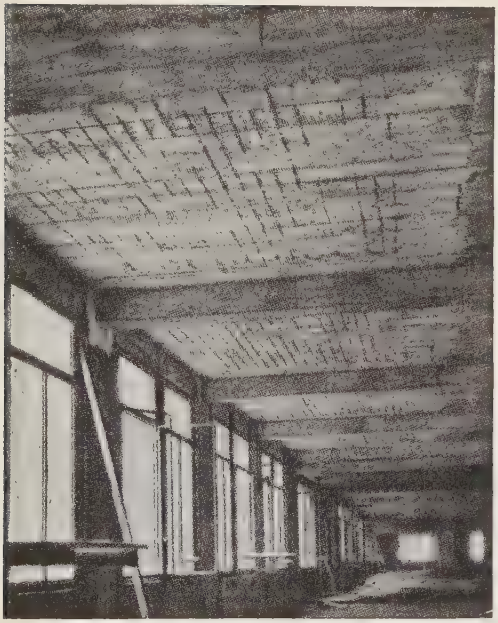


Fig. 7.

istics of heating by invisible panels at a low temperature, applications of which we will now consider, sited both in the ceiling and on the floor; the siting of the coils in the walls has not been developed to the same extent.

Heating through the walls is used in very cold places to complete heating from the floor or ceiling. In operating rooms, this has also been done to achieve a better distribution of heat.

Heated outer walls have been used for heating terraces or for forcing plants out of doors.

During our report we will give the special characteristics of each of these methods. We will also deal with the objections that have been put forward.

A. — Ceiling heating.

1° *Installations laid down during the construction of the building.*

The use of panels is possible whatever the type of ceiling : thick concrete slabs, slatted plaster, hollow plaster ceiling laid on metal or wooden joists.

In the case of thick slabs, the coils are sited on the framing (Fig. 6). Before being encased in the concrete they are tested under pressure at 40 atm. for 24 hours. During this test all the welds are hammered to check their quality and strength.

The coils are then covered by a layer of concrete on which the reinforcement for the slab is laid. The concreting of the slab takes place on routine lines. When the framing is removed, the coils can be seen on the bottom of the slab. (Fig. 7).

The job is completed by applying a

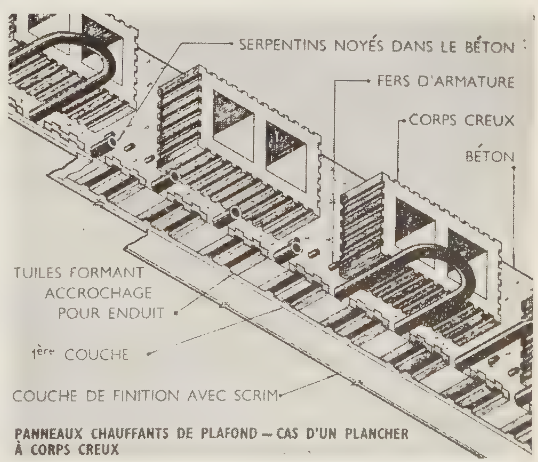


Fig. 8.

layer of a sealing compound so that no cracks will occur at working temperature. The paint used must not contain any oil; otherwise the heat would make it turn yellow.

Experience acquired over more than 30 years has enabled this technique to be thoroughly perfected. In a room with ceiling heating, it is impossible to see the position of the coils, there are no cracks, nor any discoloration of the paint.

Anyhow the small amount of heat which reaches the floor or parquet above is not lost; it contributes to the heating of the floor and the room above.

This is taken into account in the calculations.

In the case of slabs on beams when the beams are close together, as is often the case, and are laid on metal framing, the coils are fixed on the underside of the beams.

Fig. 9.

At times, to facilitate the adhesion of the ceiling, tiles or other earthenware products are used (Fig. 8).

As the heat must be directed downwards, it is essential to prevent it being conducted upwards. With this object in view, an insulating layer which will not conduct the heat is placed between the upper side of the slab and the flooring, either of cork or light concrete. In any case, owing to the position of the pipes on the underside of the slab, the heat spreads downwards more easily. The resistance to the passing of the heat is less through the thin ceiling than through the thick slab.

The coils are covered in by metal sheets which form the sheathing and take the sealing compound. Insulation above is assured by means of cork. Another method is to run in a layer of light concrete of the cellular type after the coils have been put in position and a framing made, so that the pipes are covered by it and thermic insulation upwards is obtained by having hollow spaces filled with air between the beams.

The fairly common practice of using hollow spaces makes it possible to have ribbed slabs and to anchor the coils, as well as to provide proper thermic insulation (see Fig. 8).

Finally, in the case of ceilings laid on metal or wooden joists, the coils are fastened to the joists and then covered by metal lath. Insulation is assured by slabs of cork.

Figs. 6 to 8 show applications of steel pipes according to a technique which has been mainly developed in Great Britain, and then spread to other countries.

Figs. 9 and 10 show the use of copper pipes, according to a technique invented in the United States. In such applications, the pipes are generally fixed to metal sheeting applied to the underside of the ceiling. The pipes are covered in by plaster.

Fig. 9 shows the pipes being put in place, an extremely easy operation owing to the flexibility of small diameter copper pipes.

Fig. 10 shows the first layer of plaster being applied which encases the pipes and partly covers the metal sheeting. The work is completed by applying a second layer of plaster which forms the final ceiling.

Fig. 10.

2º *Installations carried out after the building has been completed.*

Whatever the kind of ceiling be, concrete slab or ceiling laid on metal or wooden joists, it is possible to affix steel or copper coils and then cover them in by using metal sheeting to facilitate the application of the sealing compound. Insulation is obtained either by cork slabs or by hollow air-filled spaces between the joists

To sum up, in both old and new buildings, it is possible to use the ceiling as the source of radiant heat; numerous applications have proved it.

Replies to certain objections.

1º Is there not a danger of the pipes deteriorating from the outside or becoming blocked up inside?

Damage to the outside of steel pipes is no more likely to occur than damage to the reinforcement metal used with reinforced concrete. Every day experience shows that when concrete buildings are being demolished, the reinforcement

comes out cleaner than when it was laid. There is no trace of rust whatever.

Experience has also proved that copper is not affected by plaster.

As for the interior of the pipes, both steel and copper, furring up is not possible as the temperature of the water does not exceed 50° C. (122° F.) and the same water is used all the time. When a radiator heating installation is being dismantled, it is found that the pipes are never furred up, although the temperature of the water may be as high as 90° C. (194° F.) in such installations.

2° If repairs are required owing to leaks is it possible to carry them out?

The danger of leaks is extremely rare owing to the precautions taken in selecting the materials and the severe tests the steel coils have to pass before they are covered in.

In the case of copper pipes, the absence of joints and the tests carried out before they are covered in, give a similar guarantee against trouble.

If by some accident due to an outside source, for example a hole drilled in a pipe by mistake, a leak occurs, it will show near its source, so all that is necessary is to remove the sealing compound, repair the pipe by autogenous welding or braising, and re-seal it.

It should be remembered that the same risks arise with all pipes enclosed in walls, and they have not lessened the current practice of hiding the piping as much as possible.

3° If the heating fails during frostly weather, is there not a danger of the pipes splitting?

Frost damage is much less likely in the case of a panel heating system than in the case of radiators. It would in fact take several days for pipes encased and protected by a ceiling to get frozen up. So there is always time to empty them out if the installation is accidentally or voluntarily put out of work.

Should the pipes freeze up, it is not always impossible to repair them.

The Turnhout barracks are a proof of this. The heating installation consisted of thousands of yards of encased pipes. During the German occupation, the whole installation was frozen up. Discovering the leaks and repairing them was made more difficult in this case owing to the presence of a thin grooved sheet of steel under the coils. This sheet encased the coils and its grooves assured the proper adhesion of the ceiling. Repairing the installation was a very costly job, a great many welds had to be made, but only a few dozen yards of pipe had to be replaced It would certainly have been just as costly to repair a radiator installation.

4° Is not the inertia due to the great mass of the ceiling an obstacle to working this method, and does it not give rise to excessive heating when there is a quick variation in the outside temperature, particularly when the sun is shining?

Tests carried out in Switzerland, comparing two similar rooms, one of which was heated by steel coils in the ceiling and the other by radiators, showed that in spite of turning off the heat at night, the installation warmed up more quickly in the morning with radiant heating.

After the sun had been shining four to five hours continuously, the increase in

the temperature was no greater in the room heated by radiation than in that equipped with radiators.

When the windows were closed, the temperature increased faster in the room heated by radiation than in the room heated by radiators.

These favourable results can easily be explained when it is remembered that the coils in the ceiling lie very near the room side, so that the radiation of heat into the room begins long before the whole mass of the ceiling has been warmed up.

Thanks to the small difference in temperature between the ceiling and that of the air in the room and its walls, the smallest variation in the temperature of the room and its walls has a relatively important influence and automatically corrects such a variation very rapidly and consequently affects the amount of heat emitted.

On the other hand, radiators with a higher temperature continue to give out heat.

These phenomena are explained by the fact that the exchange of heat by radiation between two walls works according to a law which is a function of the difference between the fourth powers of the temperatures of the walls.

Any decrease in the temperature of the walls to be heated accelerates the emission of heat by the heating surface.

Any increase in the temperature of the wall to be heated puts a brake on the emission of heat by the heating surface.

This explains what happens when one wall is heated by the sun. Surfaces suddenly heated by the sun are no longer capable of receiving a large amount of heat owing to the above mentioned law.

There is therefore natural automatic regulation in the desired direction.

It should be noted that in the case of copper pipes encased in plaster, the mass to be heated is appreciably less, and consequently the inertia effects are less accentuated.

3° *Van Dooren system of radiant heating.*

Van Dooren, a Dutchman, has patented a system which only differs from those described above by the fact that the coils are used as the reinforcement for the concrete.

This technique is completely defensible since pipes encased in concrete are just as durable as the ordinary reinforcements used.

The « Seco » Office, which deals with building safety regulations in Belgium, agrees that the pipes of the heating panels can form a percentage of the necessary reinforcement varying with the type of slab used, its dimensions, the load carried, etc.

This confidence in the way the pipes will stand up in use has been confirmed by checks carried out in Great Britain by an official commission which selected certain buildings equipped with panel heating and chose certain of the panels in those buildings to be taken down.

The pipes were submitted to various tests and the results were entirely satisfactory.

4° *Coils kept separate from the concrete, fed at a higher temperature.*

Amongst the numerous applications of radiant heat, the Americans have invented methods in which the coils of pipes are completely independent of the concrete.

In support of such methods they claim the ease with which repairs can be carried

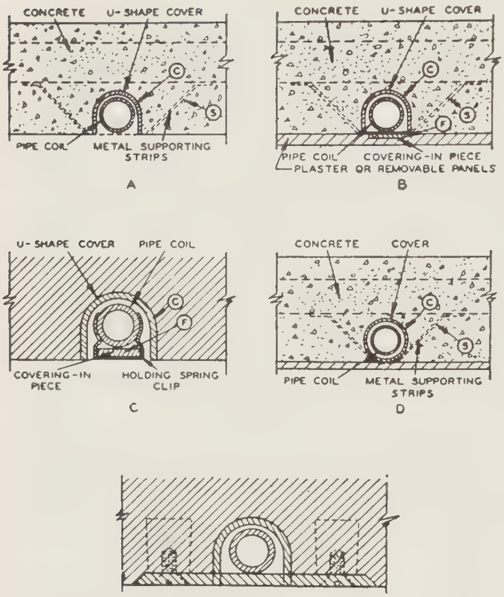


Fig. 11.

out if needed, involving only a small part of the ceiling instead of the whole of it. It may be objected that this very independence prevents the pipes being protected as they are when encased in the concrete or plaster, and reduces the guarantee against damage.

Another advantage claimed is the possibility of feeding the coils either by hot water at the same temperatures as are used with convection heating, i. e. up to 90° C. (194° F.) or even by low pressure steam (at about 100° C. [212° F.]). Such temperatures make the problem of conserving the sealing compound and the colour of the paintwork more difficult.

The sketches shown in Fig. 11 show certain methods of fitting the coils independently, and in the case of *E* show how access is obtained if repairs become necessary.

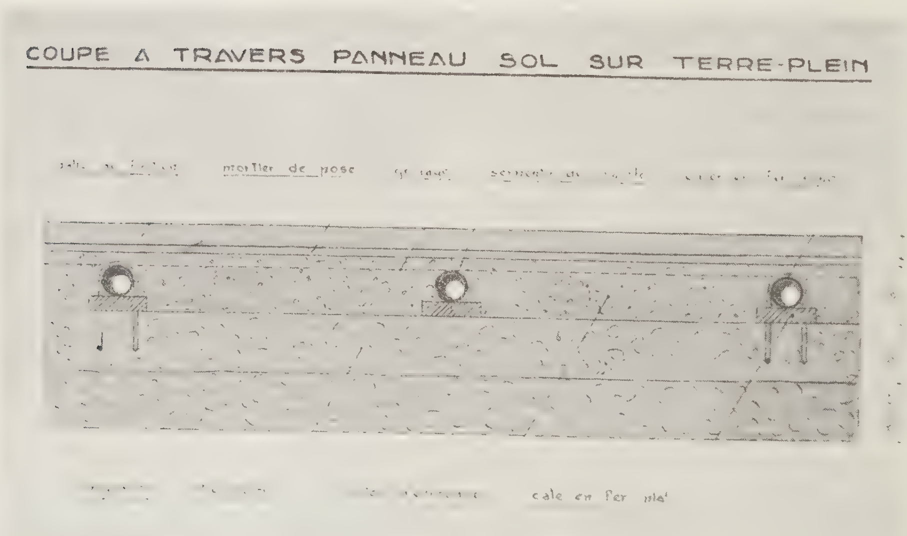


Fig. 12.

Fig. 13.

B. — Floor heating.

1° *Encased panels resting directly on the ground.*

It is possible to heat rooms at floor level even if there are no cellars.

After the ground has been levelled off, a layer of brickbats 8 to 10 cm. (3 1/8" to 4") thick, is put down, on which 8 cm. of concrete is laid, with a level surface.

The pipes, laid on wedges and kept in place by straps to make sure they will not get out of place while the concrete is being laid, are encased in 8 cm. of concrete. Finally the floor is cemented (Fig. 12).

This system is particularly suitable for large halls with high ceilings.

Fig. 13 shows copper pipes being laid for incorporation in the floor. The ease with which the work can be carried out will be noted.

Figs. 14, 15 and 16 show how the coils can be made on a simple gauge.

2° *Panels on concrete slabs.*

This method can be used with thick slabs, or ribbed slabs or hollow slabs.

The pipes are encased in a layer of concrete resting on the carrying member. The floor is then laid either on a layer of sand, or directly on cement.

In all these cases insulation has to be provided underneath.

3° *Deriaz system.*

Mr. Deriaz, a Frenchman, has taken out a patent for the use of fluids at a higher temperature, either hot water or steam.

The heating element consists of a

Fig. 14.

Fig. 15.

Experience has shown that the best distance beween pipes is 0.40 m. (1' 3 3/4") from centre to centre. The distribution of heat is very uniform in this way.

Practical experience has also shown that when the heated floor is covered with a thick woollen carpet, the temperature is only lowered by about 1° C. until the carpet is heated, which once again restores it to its previous level.

Parquet floors laid with this heating system have been very satisfactory, and do not show any signs of shrinking.

4° *American methods of heating through parquet floors.*

The Americans have adopted a simpler method than that patented by DERIAZ. system of pipes placed on the ground on which diffusers in the form of strips of aluminium sheet are fitted (Fig. 17).

The diffusers, which are good conductors of heat, distribute the heat they receive from the pipes in which the water circulates, throughout the brick partitions, which makes it possible to heat a large area with a small number of pipes.

The temperature of the diffuser is at its highest near the pipes, but these are insulated from the partitions by layers of air, the thickness of which decreases as the temperature of the diffuser falls. At one end, the diffuser is in direct contact with the partition.

The pipes are protected by a sealing compound against atmospheric effects. They are so arranged as to be completely free of and independent of the building. In this way they are able to expand freely.

Fig. 16.

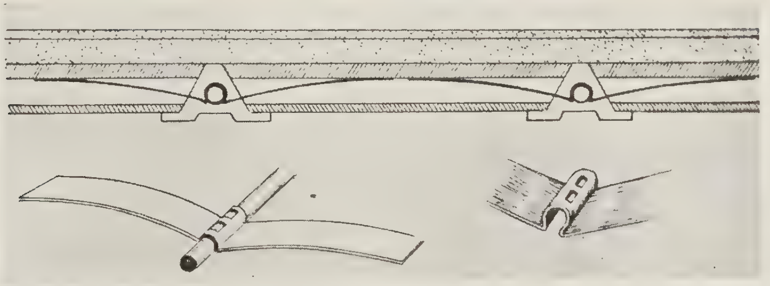


Fig. 17.

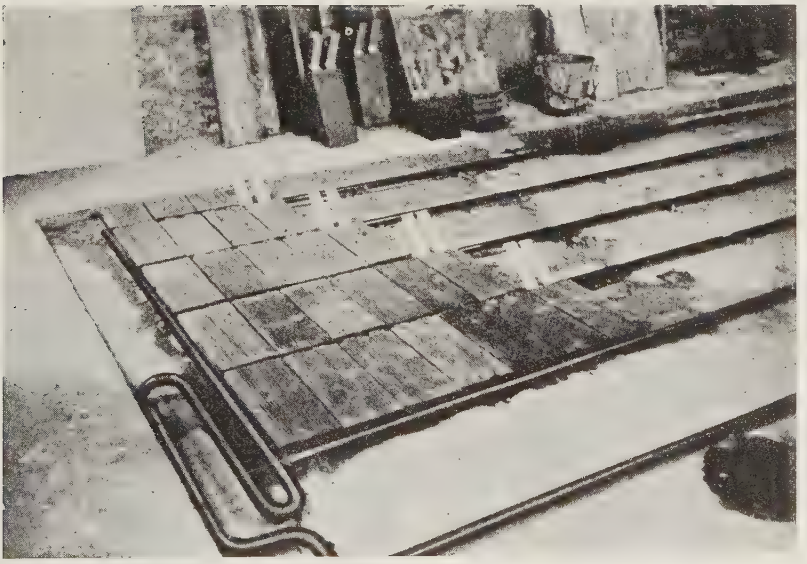


Fig. 18.

The pipes are laid directly under the parquet, without any diffusers or brick-work.

The sketch shown in Fig. 19 gives two such applications. Under *E*, can be seen heating under a parquet floor laid on the ground. Under *F*, heating under the parquet on a upper floor.

In both cases, the parquet consists of a double layer of wood boards.

To prevent shrinkage and gaps between the joints, the following precautions are advisable:

Before being laid, the boards are put in a drying plant until the moisture content has been reduced to 5 or 6 %.

Drying off is then completed on the spot by placing the boards on joints already heated by the heating fluid running through the pipes (Fig. 20).

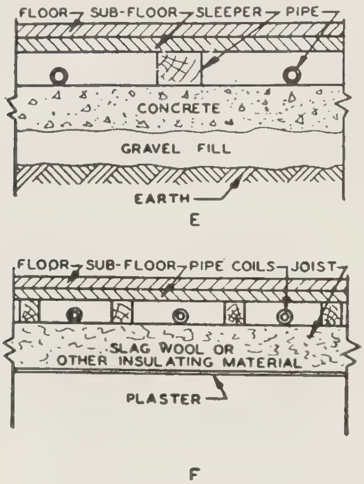


Fig. 19.

It will be noticed that there is a layer of insulating material between the joists in order to reduce to the minimum the loss of heat downwards.

When the wood has completely dried out, it is nailed down to the joists.

C. — Field of application of ceiling, floor or wall heating.

Where should the heating panels be sited? In the ceiling, in the ground, or in the walls?

If the ceiling is used, it is possible to emit a greater number of calories than when the floor is used, as a higher temperature is permissible without causing any inconvenience. It would be unpleasant to spend much time on a heated floor if the heat was too great.

Ceiling heating is therefore advisable in the case of living rooms, dining rooms, offices, schools, etc. It should be noted that some of the heat reaches the floor and increases the feeling of comfort, since loss of heat through the feet is reduced.

Floor heating is indicated in the case of rooms directly on the ground, or those with paved or marble floors : for bathrooms, passages and halls. It can be used in large buildings of great height, such as churches, museums, large halls.

Floor heating makes it possible to obtain heating outside, in the case of terraces in sanatoriums, cafes, open galleries, petrol stations, bus stops, etc.

Deriaz heating is suitable for paved or parquet floors. The fact that the heating fluid used is at a higher temperature than with the other types of heating


Fig. 20.

panel makes it possible to provide floor heating in certain rooms of a house without difficulty and without having special equipment, while other rooms can be heated by radiators.

This feature of combining panel heating and radiator heating is not confined to the Deriaz system. With a steam installation with which certain rooms are heated by radiators, it is possible by using a converter to feed the panel heating circuits with hot water.

If it is question of a hot water plant, the use of converters or mixing circuits also makes it possible to use both radiators and heating panels.

A combination of ceiling and floor heating is used in certain cases where each method by itself is insufficient.

Heated walls are used in certain very cold places to complete ceiling and floor heating. This is particularly useful in the case of operating theatres.

Interesting applications of radiant heating have just been made in Belgium in workmen's houses. The smokestacks which are usually made of brickwork as vertically as possible. have been replaced by ducts of the « Shunt » type which makes it possible to have either a direct draught or draught through a heat recovery duct.

The walls of these ducts are heat radiating surfaces and warm the upstairs rooms.

Figs. 20' and 20'' give details of this method of heating.

Heated outside walls can be used on terraces or for forcing plants out of doors.

It should be noted that ceiling heating affords greater scope in the utilisation of the room, since the putting of furniture on the floor or against the walls interfers with the regular emission of heat when the screening effect of such furniture has not been taken into account in calculating and siting the heating panels.

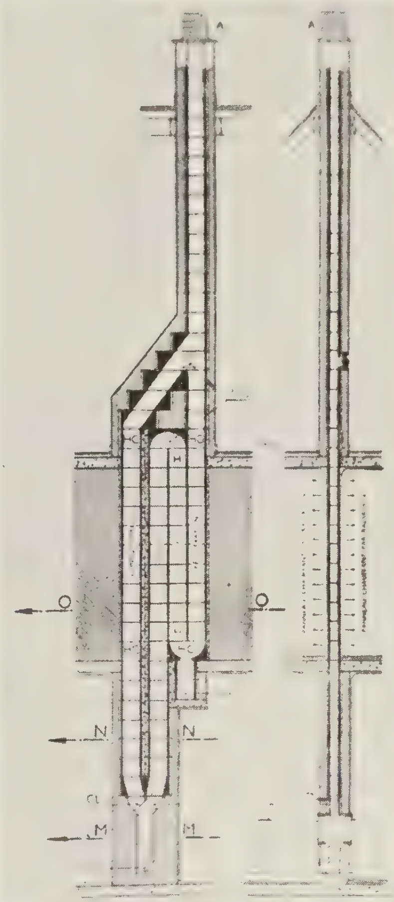


Fig. 20'.

D. — Some references.

When consulting the reference lists of the main firms working these patents, it is found that all types of buildings are

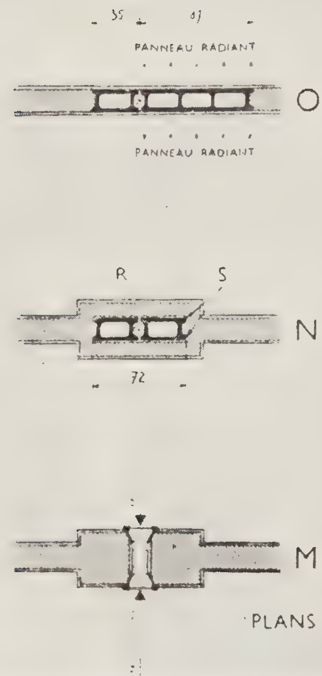


Fig. 20''.

concerned. We give below certain examples selected at random from a great many others :

Banks :

Bank of France	Paris.
Bank of Spain	Madrid.
Milan Agricultural Bank .	Milan.
Bank of England . . .	London.
Hong-Kong and Shanghaï Bank	Hong-Kong.
Kobenhavns Handelsbanken	Copenhagen.

Hospitals :

Hôtel Dieu	Rouen.
Municipal Hospital . . .	Neuilly.
El Kettar Hospital . . .	Algers.
C. N. A. S. Sanatorium . .	Rome.
King's College Hospital .	London.
Metropolitan State Hospital	Waltham Mass.
University College Hospital	London.
Children's Sanatorium . .	Copenhagen.
Sabbatsberg Sjukhus . .	Stockholm.
British Hospital	Montevideo.
Hospital	Bale.

Offices :

Shell Company's Offices .	Paris.
Liquid Air Company's offices	Paris.
Electricity Supply Co. . .	Maastricht.
Norra Slingen Vid Slussen	Stockholm.
Royal Liver Building . .	Liverpool.
Australia House	London.
Imperial Chemical House .	London.
Soc. An. Porti Eciare . .	Rome.
Régie des Télégraphes et Téléphones	Brussels.

Schools :

Ecole d'Infirmières de l'Hôpital N.-D. du Bon Secours	Paris.
Maison des Etudiantes . .	Bordeaux.
Gymnasium	Prague.
Institut Français	London.
Kugl. Tekn. Hogskolans Kanai	Stockholm.
University	Pisa.
Ecole Birkero	Denmark.
Chelsea Polytechnic . .	London.
Railway Training College Dehra Dun	India.
School of Agriculture . .	Cambridge.
School of Mineralogy . .	Cambridge.
Trinity College Library . .	Oxford.
Scuole Ronchetto . . .	Milan.
Open Air School . . .	Amsterdam.

Applications might also be quoted in the case of churches, hotels and restaurants, newspaper offices, private residences, shops, public establishments, etc.

Readers interested in any of these special cases, can easily obtain details by writing to the firms holding these patents.

We have given certain examples with the object of showing that applications have been made not only in temperate climates such as in France and Great

Britain, but also in northern and southern countries.

In the latter case, it should be noted that ceiling heating is of particular value, as it is possible to cool the rooms thereby in summer, by circulating cold water in the coils. The cooling effect is due on the one hand to radiation, and on the other to the cold air falling down from the ceiling.

Finally it should be noted that in the lists there are examples of successive applications carried out on behalf of the same organisation, a proof that the first applications were found satisfactory.

For example we may mention :

1° Five installations in buildings owned by the University of Cambridge : the Schools of Agriculture, Mineralogy, Petrology, Physiology and Zoology, as well as the lecture hall and extensions to King's College;

2° Barclays and Martins Banks have many of their branches heated by radiation;

3° Boots Pure Drug Co. Ltd. has nine branches in Great Britain heated by radiation.

E. — Advantages found.

a) Aesthetic. — As the heating installations is completely hidden, the usual methods of camouflaging radiators are unnecessary.

b) Comfort. — With the same degree of heat, the temperature of the air in the case of radiant heading is 1° to 3° lower than in the case of heating by radiators.

It should also be noted that the distribution of the heat on the level and upwards is much more regular with radiant heating than with convection heating.

The graphs given in Figs. 21 and 22 bring out these advantages.

c) Cleanliness. — As the movement of the air is reduced in the case of radiant heating, there are no black trails of dust left on the walls.

d) Hygiene. — There is no carbonisation of the dust in contact with the radiators. As the dust is no longer disturbed by the movement of the air, it does not get mixed with the air that is breathed in.

e) Cooling in summer. — We have already mentioned this advantage.

f) Fuel economy. — The operation of radiant heat installations results in a fuel saving ranging between 10 and 25%.

g) *Ventilation.* — It is possible to open the windows to renew the air without inconveniencing the occupants of the room.

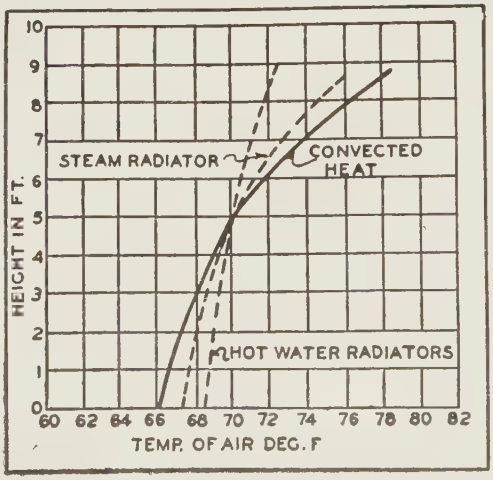


Fig. 21.

h) *Reduced maintenance.* — All parts of the installation, distribution pipes and coils, are usually covered in, so they do not have to be painted.

i) *Saving in the reinforcement.* — With the Van Dooren system, it is possible to reduce the reinforcements used for the reinforced concrete, since the coils of pipes are used to increase the strength of the reinforced concrete.

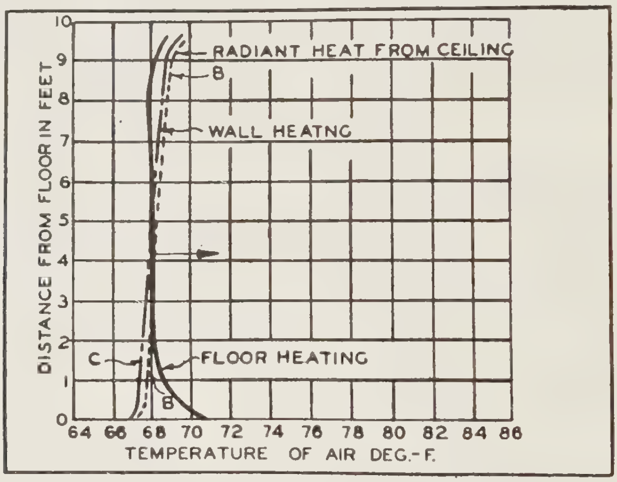


Fig. 22.

F. — **Precautions dictated by experience.**

a) Association of concrete with the pipes.

1° *Action of heat on concrete.*

Concrete can stand up to a temperature of 200° C. (392° F.) without deterioration.

The use of pipes heated to 50° C. (122° F.) has no destructive effects on concrete.

According to Professor MAGNEL of the University of Ghent, heating has however the effect of retarding and even stopping the hardening of concrete owing to the drying up it occasions. Consequently the heating must not commence until the concrete has hardened sufficiently, which usually means a delay of at least 28 days.

2° *Effects of heat on the adhesion between the concrete and the pipes.*

Care must be taken that the adhesion between the concrete and the pipes is not broken. This would result in premature ageing of the slab. In addition the protection given to the pipes by the concrete would be destroyed.

In the Van Dooren system, the drawbacks would be still greater, as the main principle of reinforced concrete is the perfect solidarity between the concrete and its reinforcement.

According to the experiments carried out by Professor Ros, Director of the Federal Test Laboratory at Zurich, there is no danger of breaking the adhesion,

even when the temperature varies as much as 35° C., provided heating does not go up by more than 2° C. per hour.

As regards the association between copper pipes and plaster, it should be noted to begin with that plaster is one of materials best able to stand up to heat, and also that its coefficient of expansion is 0.000111 and that of copper 0.000112, so that there is no danger of the adhesion being broken.

3° *Action of heat on deformations.*

According to Professor Ros, the final deformation will be double that which would occur in a non-heated slab.

Precautions have to be taken when the walls are carried on heated slabs of extensive size.

b) The heating panel as a unit.

1° *Case of buildings with supporting walls.*

One example of a crack is worthy of note, since practical conclusions can be drawn therefrom.

A slab resting on four walls cracked on cooling. This slab when expanded exercised a thrust upon the walls to which it was fastened. When it cooled, the fact that it was fastened to the walls prevented it from contracting and a 2 mm. (5/64") crack occurred in the middle of the panel, parallel to the main reinforcement.

When the panel was examined, the conclusion was come to that the calculations had taken into account the flexibility of the slab in one direction only whereas it should have been able to bend in both directions. The reinforcement in consequence was insufficient, so that the damage which occurred could not be ascribed to the heating.

The fact that the panels must be able to expand must never be overlooked. A space should be left between the outer edge of the panel and the wall in order to avoid a thrust being exerted on the wall. Finally the contraction of the concrete on cooling must be facilitated by providing a supporting surface between the slab and the wall upon which it can slide. In certain cases, zinc plates have been put between the wall and the panel. As regards the space between the wall and the panel, this can be closed by some highly compressible material, such as corrugated paper, to prevent the joint being filled in with solid matter whilst building is in progress.

2° *Case of buildings with a complete framework of reinforced concrete.*

When the panels are carried on beams and columns forming a monolithic whole, the danger of cracks occurring is less. Certain relatively unimportant damage may however occur, such as hair cracks in the panels and partitions.

This means that the building should be carrefully planned, as by taking various precautions taught by experience it is possible to avoid these drawbacks.

G. — Effects of radiant heating on the interior finish of buildings.

Certain drawbacks were encountered in the first applications of radiant heating. They were not very important, and had no effect on the stability of the building, as they only affected it aesthetically. The technique of the interior finish is now thoroughly perfected.

1° *Sealing compounds.*

The composition of the sealing compounds has been thoroughly perfected. It is advisable to include jute canvas in the compound to bind it together and prevent hair cracks.

Precautions must be taken where two different materials forming part of the main structure meet, as well as around the heating panels. If there is a joint in the main structure, there must naturally be a corresponding joint in the sealing compound.

It should be noted that such precautions have to be taken in all buildings, whether equipped with heating panels or not.

2° *Parquet floors.*

Experience has shown that parquet floors do not shrink appreciably when heated to a moderate degree, especially with the Deriaz system.

3° *Paved floors.*

The problem of the tiles lifting is of special importance. It is advisable to lay the tiling on a thin layer of sand rather than to lay it with cement directly on the concrete.

4° *Painting.*

As we have said above, paint containing no oil alone is used.

II. — PANELS FED DIRECTLY BY STEAM OR SUPERHEATED WATER.

A. — Panels made of steel pipes.

We mentionned in the paragraph dealing with the siting of the panels (ceiling, floor or walls), that it was possible when a high temperature fluid was available, whether water or steam, to supply hot water at low pressure at a low temperature for emitting radiant heat at a low temperature, thanks to the use of heat exchangers.

In industrial applications, steam or superheated water is used to feed the coils directly.

There would appear to be a contradiction between this practice and the criticisms formulated at the beginning of this study against the use of radiant heat at a high temperature.

The contradiction is only apparent however, as in the method criticised it was not so much the high temperature of the heating surface which was condemned as the insufficient distance between the heating surface and the occupants of the room.

In the applications in current use in industry, coils fed by a fluid at a high temperature distribute the heat over the emitting surface, which reduces the temperature. On the other hand, the distance between the heating surfaces and the occupants is so planned that no inconvenience will be caused.

1° « *Crittall Sunzway* » *panels.*

The Crittall Sunzway panels can be fed by hot water or steam at low or average pressure. However, when the engineer can choose the fluid to be used, superheated water is recommended. In this case the emitting surfaces can be reduced in area owing to their higher temperature. It also makes it possible to have a wide range of temperatures,

which can be selected according to weather conditions.

The constitution of the panels.

Crittall Sunzway panels are of two types :

a) Panels with only one radiating face;

b) Panels with two radiating faces on opposite sides.

The single panels consist of a steel sheet on which 1/2" coils of pipes are welded. The ends of the coils extend beyond the edges of the panel and are connected to the feed and return pipes (Fig. 23).

The back of the panel is covered with an insulating cover with a reflecting surface on the inside. Care is taken that there is no contact between the coils and this cover, to prevent any loss of heat through conductibility.

The panels with two radiating surfaces are made in the same way, but the cover at the back is replaced by a second radiating plate welded to the coils. The edges are welded all round (Fig. 23).

After being put in position, the panels are painted, preferably with a mat rugose paint favorable to radiation.

Arrangement.

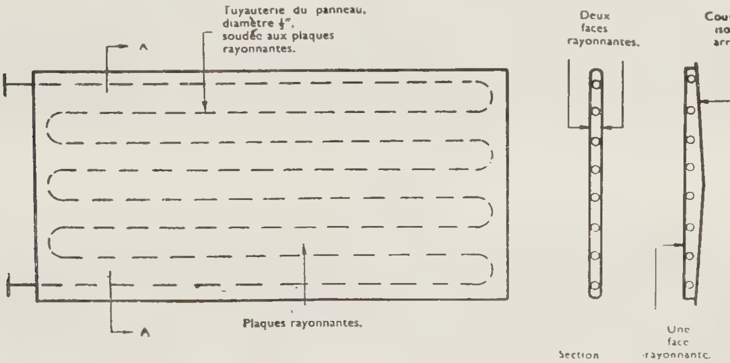
Sunzway panels must be so arranged as to radiate heat over the maximum floor space. Their radiating face can be turned vertically (Fig. 24) or horizontally (Fig. 25).

When laid vertically, the lower edge should be 2.45 to 3.05 m. (8' to 9' 11 3/8") from the floor.

The single panels can be slightly sloped to direct the heating rays downwards.

Emission of heat.

If the heating fluid is at an average temperature of 143° C. (289° F.) and the atmosphere about 15.5° C. (60° F.) the



Eléments rayonnants SUNZWAY.

Fig. 23.

Explanation of French terms :

Tuyauterie du panneau, diamètre ½", soudée aux plaques rayonnantes = Panel piping, diameter ½", welded to the radiating faces. — Deux faces rayonnantes = Two radiating faces, section A — A. — Couvercle isolant arrière = Back insulating cover, one radiating face.— Eléments rayonnants SUNZWAY = SUNZWAY panels.

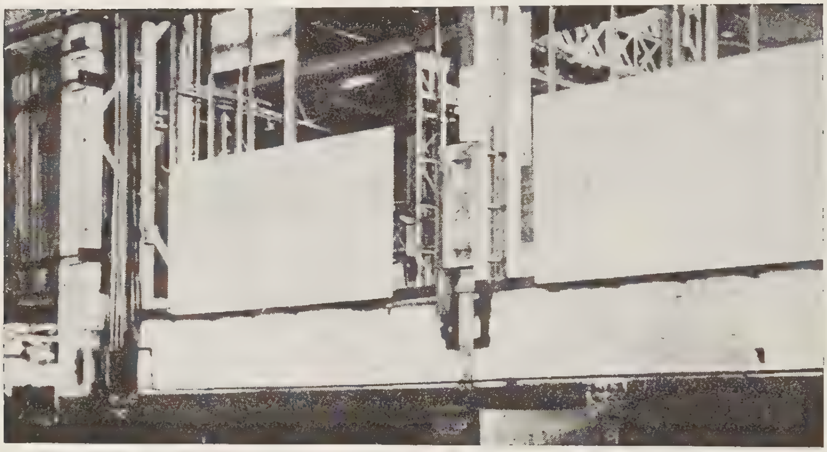


Fig. 24.

Fig. 25.

estimated power is 1 355 calories per square metre.

According to this basis, the standard 8' × 4' panels can emit 4 000 calories in the case of a single panel and 8 000 calories in the case of a double panel.

The panels can be controlled by the usual automatic regulation of radiant plant (mixing shutters, zonal or individual thermostats).

Fig. 26 shows Sunzway panels fitted in a shop.

The maximum width between vertical panels is 100'.

These distances show that it is possible to heat very large halls by means of Sunzway panels.

Fig. 27 shows the vertical panels in a factory : the Ruston Bucyrus Excavator Works at Lincoln (England).

being used, to allow the sheet and the pipes to expand freely. Perfect contact between the pipes and the sheet is obtained by means of a compound with an asphalt and benzol base.

The heating fluid can be either water or steam, either at 80° C. (176° F.) or better still superheated water, making possible

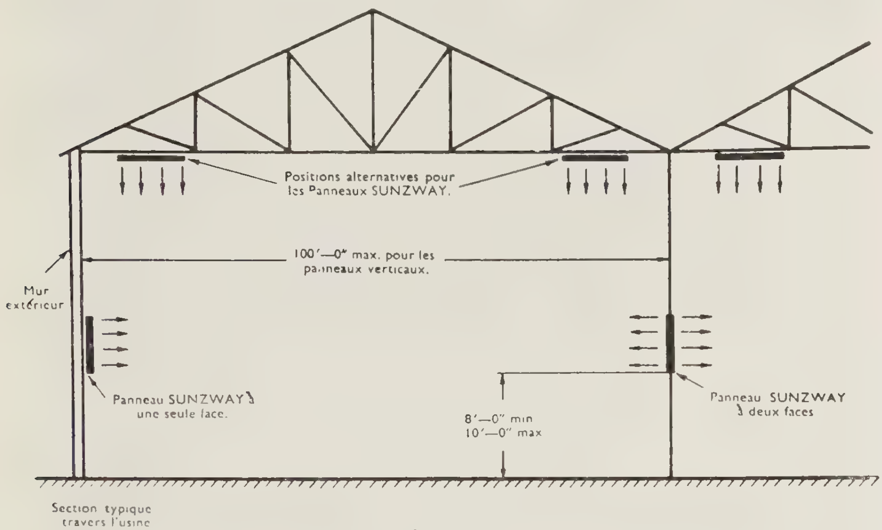


Fig. 26.

2° *Crittall Sunstrip radiant panels.*

These panels are sited in continuous bands on the girders or other members whence the rays can be directed onto the occupants or machines without interfering with the natural light.

Fig. 28 shows the arrangement in plan and section of these panels.

They consist of a 12/10 mm. (30/64"/25/64") pressed plate on which 40/49 or 26/34 mm. (1 37/64"/1 15/16" or 1 1/32"/1 11/32") pipes are set, perfect contact being assured by collars and no welding

a range of temperatures from 80° C. to 130° C. (176° to 266° F.). The temperature adopted determines the height at which the panels are sited. For example :

Height.	*Maximum temperature.*
4 m. (13' 1 1/2")	80° C (176° F.)
5 m. (16' 5")	100° C (212° F.)
6 m. (19' 8 1/4")	120° C (248° F.)
7 m. (22' 11 5/8")	130° C (266° F.)

The inner face of the sheet is painted to give a mat, broken surface. Black is not used because of its appearance, even though

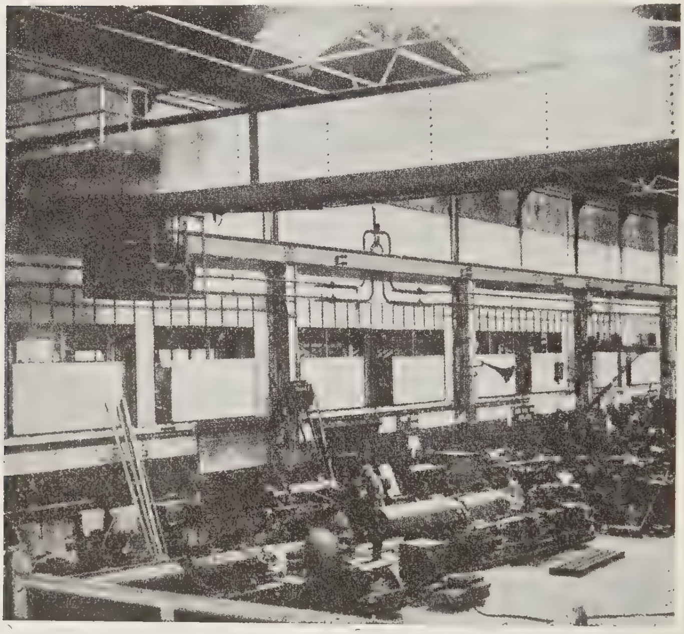
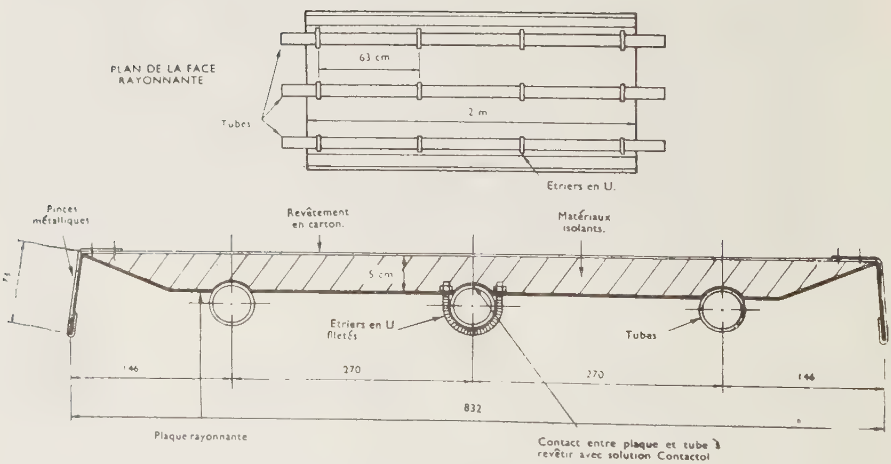


Fig. 27.



SUNSTRIP PANELS

Fig. 28.

it is the best conductor. Experience has proved that cream, so long as it is mat and rugose, does not reduce the efficiency too much.

The upper side of the sheet is carefully lagged by glass silk in rolls, cork or mineral wool slabs.

on the other to make good in part the losses due to the glazed lights, without increasing too much the temperature of the upper part of the shop.

The coefficient of emission which can be taken as a basis for calculation is 9 calories for each degree of difference between

Fig. 29.

Emission of heat.

The emission of heat takes into account both the radiation downwards in the form of a cone reaching down to the ground which is covered to an extent depending upon the angle of inclination of the panels, and the convection, which is limited by the turned up edge of the sheets. This convection serves on the one hand to maintain constantly on the surface of the panels a layer of air at a high temperature, and

the mean temperature of the surfaces of the steel sheets and the surrounding air.

Fig. 29 shows how Sunstrip panels are fitted in a garage in Brussels.

This brief report on Sunzway and Sunstrip panels shows their great possibilities. It is possible to heat an entire hall or only part of it in this way. We will return to this subject when drawing up our conclusions on the application of radiant heat in railway installations.

B. — Panels made up of copper pipes.

Fig. 30 gives details of a panel consisting of copper pipes, oval in section, set in grooves in a pressed metal sheet. The right hand drawing shows the finished panel after the cover has been put on under pressure.

Fig. 31 shows another type of radiant panel, with cooper pipes of circular section.

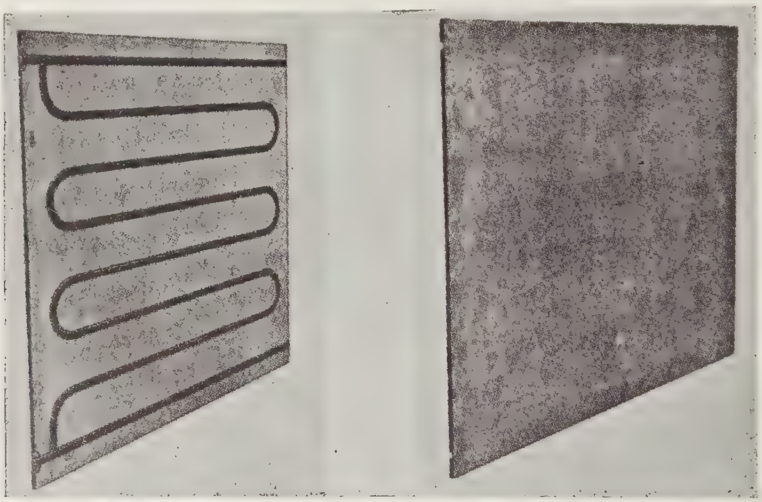


Fig. 30.

The base consists of a fibre plate covered with reflecting material. The pipes are spaced by means of supports. They are oxidised in order to increase the radiation.

A plate is set in contact with the pipes to make the outer radiating surface.

C. — « Rayrad » cast iron panels.
(Fig. 32 and 33.)

These cast iron panels have a smooth side and a ribbed side. The smooth side is placed inside the room to be heated, and the ribbed side canalizes the circulation of the air.

The front emits heat partly by radiation and partly by convection. The back only emits heat by convection.

It would be possible to use these panels as radiant heating panels only, but in that case the back should be insulated to prevent any loss of heat.

The 0.406 m. (1 38/64'') elements are connected together by ferrules like radiator elements.

Only low pressure feed can be used, either water or steam.

III. — FLOOR HEATING BY CIRCULATING HOT AIR THROUGH DUCTS.

Heating through the floor by circulating hot air through ducts has been successfully carried out.

This is really an up-to-date version of the Roman hypocaust which we mentioned in the Foreword (See Figs. 1, 2 and 3).

The Romans ran the heat generated by charcoal-burning furnaces through conduits under the floor. This natural circulation of the heat was limited to short lengths. In large buildings, it was necessary to have a number of furnaces.

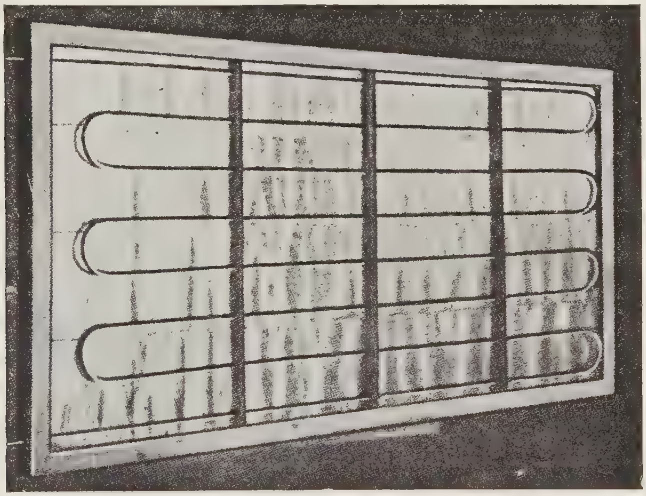


Fig. 31.

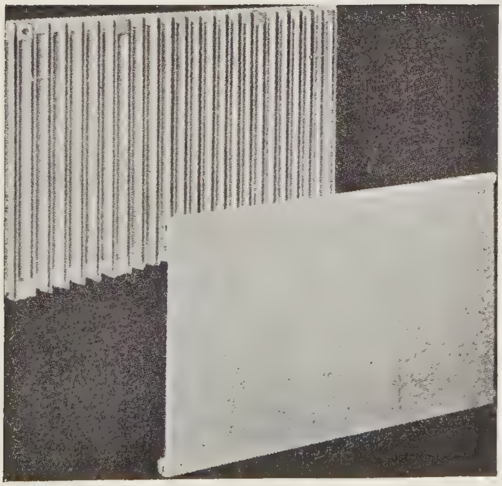


Fig. 32.

In up-to-date applications, hot air is used supplied by a steam fed set, or directly heated in hot air boilers. Circulation takes place through closed circuits by centrifugal ventilators.

Figs. 34 and 35 show in section and plan an installation of this type in a hospital building.

The output on each storey is obtained by the inlet valve shown under X on Fig. 34. This valve makes it possible to control or cut out the air.

The equal distribution of the air in the secondary conduits sited in the thickness of the floor is regulated once for all by the openings shown under Y in Fig. 35.

The heating of Liverpool Cathedral.

A remarkable heating installation by means of hot air circulated under the floor has been carried out in the superb protestant cathedral of Liverpool, the work of the celebrated architect Gilbert Scott.

The whole of the pavement of the choir,

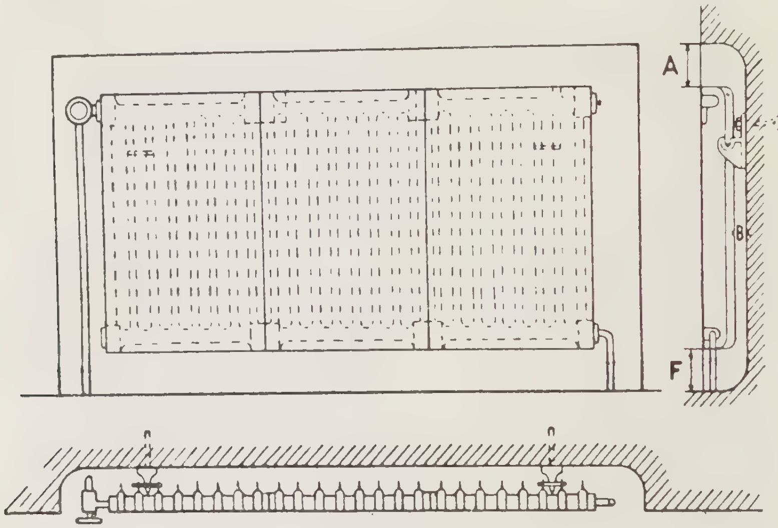


Fig. 33.

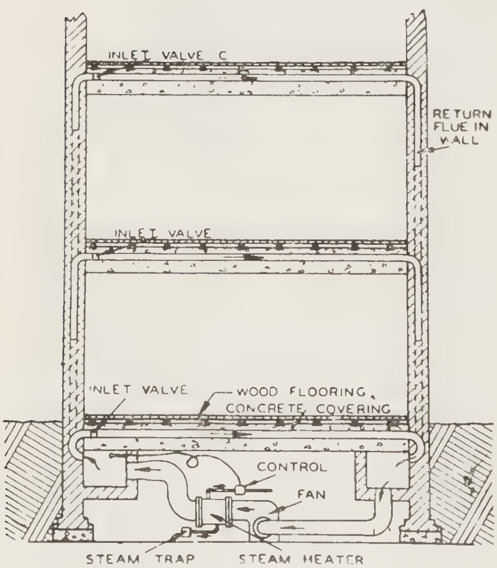


Fig. 34.

transept and nave is a single and enormous radiator, in the exact sense of the word.

As the whole floor is uniformly heated, there are no draughts and the temperature is identical throughout the cathedral at a given level.

Here are some details and the results of tests as given by the engineer, T. NAPIER ADLAM.

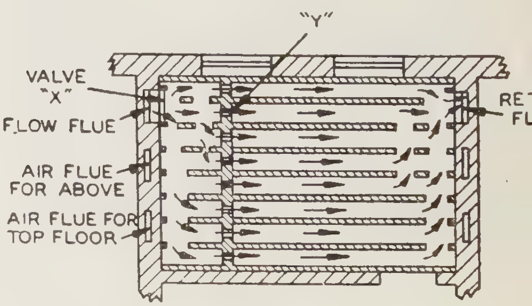


Fig. 35.

The temperature of the air circulating through the conduits varies between 120°F. and 100° F. (48.50° to 37.7° C.).

The temperature of the floor is 3.5° to 7° C. (38° to 44°6 F.) above the air temperature within the cathedral.

The height of the building is 113 feet.

The gallery around the triforium is 97 feet above the floor.

During tests the temperature at 4 feet above floor level was 60° F. (15° C.). At the level of the triforium it was 58.5° F. (14,8° C.), i. e. slightly lower than that found at 4 feet above the floor.

Mr. T. NAPIER ADLAM states that in many similar tests made by him in other cathedrals, in particular in St. Pauls in London, he has never found the temperature in the upper portion lower than near the ground. On the contrary, the temperature has invariably been greater, and too high for comfort.

Another characteristic of the installation at Liverpool is the great reserve of heat accumulated. When the burners go out, it has been found on making tests that the temperature has fallen by 1° C. only after 36 hours.

Under normal working conditions, it has been found that if the burners are in use for a few hours each day, the variations in the air temperature are so small as to be inperceptible.

One might be tempted to think that in the case of such high buildings, it is not necessary to take into account losses through the ceiling. This would be a grave mistake since the temperature of the air in the upper parts, although lower than that near the ground, is however greater than the outside temperature. There is therefore necessarily a loss of heat which must be taken into account in the calculations.

However there is no doubt that these losses are appreciably less in the case of radiant heat than with any other method of heating.

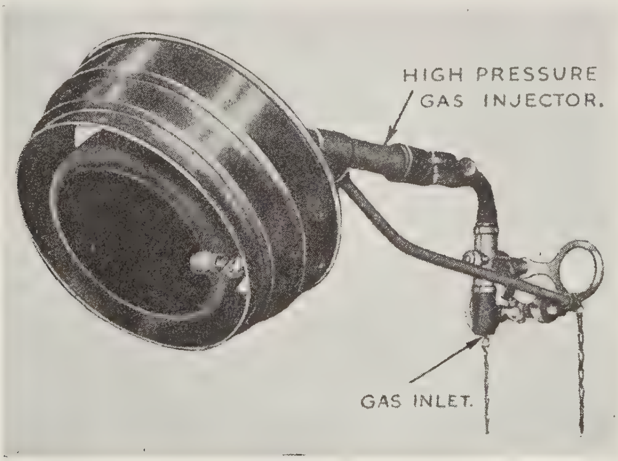


Fig. 36.

IV. — RADIANT HEATING BY GAS.

We will describe two kinds of apparatus, mainly used in industry.

The « *Radiotherme* » (Fig. 36) consists of a cast iron casing enclosing a refractory brick. The brick is regularly fed by the back with an « air-gas » mixture. Combustion takes place inside the brick and is so regulated that the zone of combustion lies near the surface. This becomes red hot and emits red and infra-red heat rays.

The *equipment* consists of two different kinds of apparatus according to the type:

a) A gas compressor (2 m. = 6' 6 3/4''), a pipe line and radiotherms;

b) An air ventilator, two pipe lines and radiotherms.

Fig. 37.

Characteristics.

Surface of bricks . .	24.7 cm. ø	(9.724 inch.)	35.5 × 10.1 cm.	(15.97 × 3.97 in.)
i. e.	488 cm²	(96.309 sq. inch.)	360 cm²	(71.04 sq. inch.)
Consumption of gas .	1.5 to 2.3 m³/h.	(1.95 to 3 cu. y. /h.)	1.1 to 1.5 m³/h	(1.43 to 1.95 cu. y. /h.)
Consumption of air .	7.5 to 12 m³/h.	(9.8 to 15.69 cu. y. /h.)	5.7 to 9.3 m³/h	(7.44 to 10.16 cu. y. /h.)
Surface heated :				
interior	31 to 39 m²	(37.07 to 46.64 sq. y.)	23 to 29 m²	(27.5 to 34.68 sq. y.)
exterior	13 to 16 m²	(15.54 to 19.13 sq. y.)	10 to 12 m²	(11.96 to 14.35 sq. y.)
Max. heating dist.. .	4 to 6 m.	(13' 1½'' to 19' 8 1/4''	3 to 5 m.	(9' 10 1/8'' to 16' 5'')

Advantages.

a) Localisation of the heating, thanks to its being emitted in a beam covering the surface of a closed or open room.

b) Speed of getting it into operation. As soon as the brick gets red hot, the emission of heat becomes regular.

c) Adaptability and economy due to the use of a thermostat which reduces the consumption of gas to the minimum.

Drawbacks.

The combustion fumes are liberated into the room. If it is large and well ventilated, this drawback is not very serious.

Field of application.

Heating the whole of a small workshop which has no other source of heat such as steam or hot water heating.

Partial heating of a hall in which the work benches only occupy part of the space.

Fig. 37 shows a small workshop heated by Radiothermes.

Intermittent or occasional heating of stands, passages, galleries, terraces, etc.

A few years ago we came across an application of radiant heating by gas in the open air under the awning in front of a large Brussels store. This awning was at least 6 m. (19' 8 1/4") above the level of the pavement.

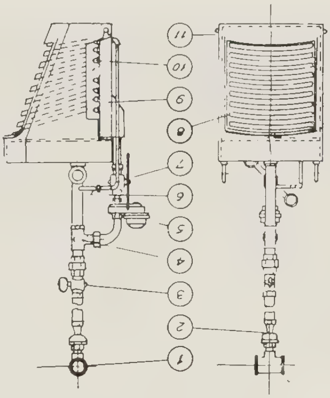
We found that the sensation of warmth was appreciable, and made it very pleasant to be under the awning.

The « Newtherm » (Fig. 38) is an apparatus directly fed from the main gas supply, without any compressor or fan.

It consists of an outer casing in which are placed refractory elements. It is fitted with a burner and a by-pass; pressure is maintained constant by means of a diaphragm regulator.

The hourly consumption is 2.6 m^3 (3.39 cu. yards) and the heat output 9 000 calories with the usual town gas.

When suspended at a height of 2.8 to 4 m. (9' 2 1/4" to 13' 1 1/2") above the floor, the Newtherm heats an area 35 to 40 m^2 (41.86 to 47.84 sq. yards).



1. - Gas pipe.
2. - Bend coupling.
3. - Stop-cock.
4. - Gas-filter.
5. - Diaphragm regulator
6. - By-pass.
7. - Lever cock.
8. - Refractory elements.
9. - Burner.
10. - Noses.
11. - Enamelled cast iron casing.

Fig. 38.

Fig. 39 shows a shop heated in this way.

The advantages, drawbacks and fields of application are the same as for the Radiotherme. It should be noted however that the Newtherm is easier to instal, as there is no mechanical equipment.

V. — RADIANT HEATING BY ELECTRICITY.

We will describe a few types of equipment and general applications of ceiling heating. The temperature of the emission

surfaces determines the classification of this equipment.

1° Low temperature electric radiant heating from the ceiling;

2° Medium temperature electric radiant heating from the walls;

3° High temperature electric radiant heating by equipment sited at a great height.

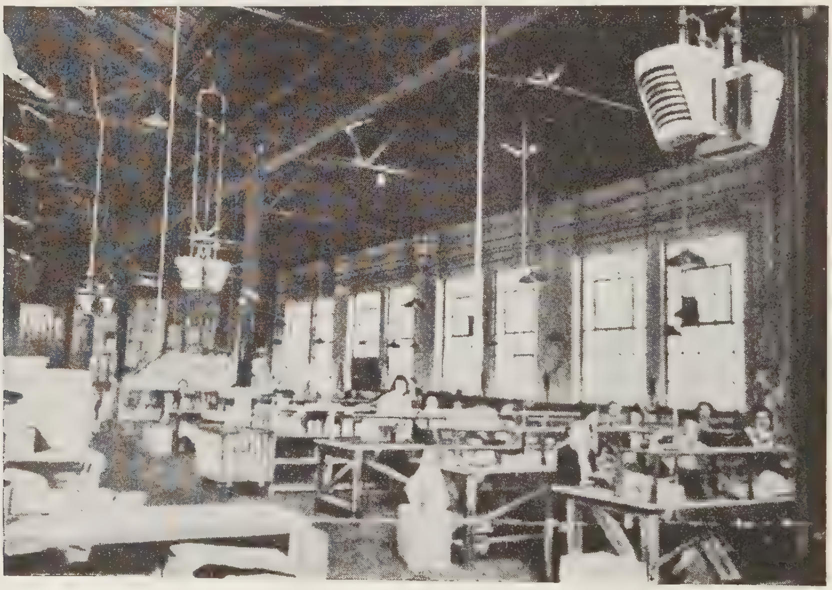


Fig. 39.

For each of these three types of heating, automatic control of the temperature is recommended in order to reduce consumption to the minimum.

1° *Low temperature electric radiant heating*

The « Dulrae » equipment described below consists of panels the surfaces of which are heated to a temperature of not more than 27 to 32° C. (80° to 90° F.). They are embedded in the ceiling and work under similar conditions as regards comfort to the ceiling heating installations fed by water at low temperature previously described.

The « Dulrae » consists of a 1 mm. (3/64'') thick woven fabric in which the heating elements are incorporated. They are made in rolls 100 yards long and 24 inches wide. Made up of 2 ft. sections, they can be cut up into panels the size of which may be any time the size of a section up to 12 ft.

It is applied to the ceiling and is connected up within the thickness of the ceiling by means of the plugs with which all the two foot sections are fitted.

The loss of heat upwards through the

ceiling is prevented by fitting insulating panels, which are also moisture and mould resisting, and vermin proof, as well as light and inexpensive. Compressed cork slabs satisfy all these conditions.

This method of insulation is similar to that described in the paragraph dealing with panel heating by means of coils of pipes.

Fig. 40 is a diagram showing how these panels are formed.

Fig. 41 and 42 show the siting of insulated cables and their encasing in order to provide ceiling heating (an application from the United States).

The cables are 1/3'' dia. and are encased in a layer of plaster to a depth of 5/8''.

When the cables are 4 1/2'' apart, the average temperature of the ceiling is raised to 46° C. (114.8° F.).

It is recommended to insulate the ceiling as perfectly as possible to prevent loss of heat upwards.

The firm of Schréder of Brussels carries out applications of similar methods.

They supply on the one hand prefabricated panels of 2 m² (2.39 sq. yards), the surface of which is heated to a temperature of 42° C. (107° F.), with an hourly consumption of 700 watts (« Panelec » panel).

On the other hand, they carry out heating through the floor, ceiling or walls by means of resistances embedded in them. The methods used are similar to those employed in the United States (See Figs. 41 and 42).

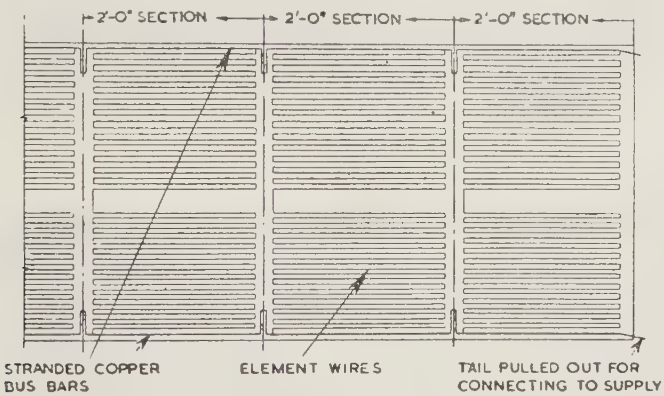


Fig. 40.

2° *Medium temperature electric radiant heating.*

The « Medrae » panels consist of 6 mm. (15/64'') thick sheets made of resin-bonded asbestos in which are embedded copper-nickel wires.

The composition of the sheets ensures both the electrical insulation and the mechanical protection.

There are also other types of equipment, in cast iron or steel, with suitable insulation.

These panels are used in houses and commercial buildings.

Fig. 41.

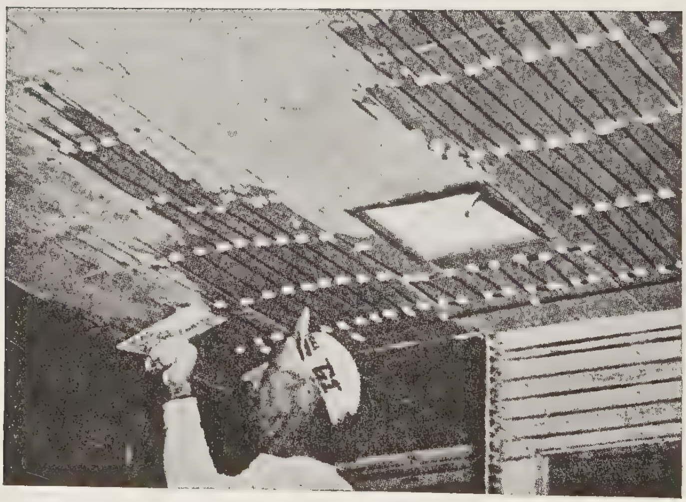


Fig. 42.

They are generally sited under the windows, particularly in the case of large windows, to overcome the currents of cold air due to the glass. It is recommended that they should not be placed too near seats that are regularly occupied, cr on ceilings less than 10 ft. high.

The panels are about 3 ft. by 2 ft.

placed a few inches away from the walls, in which case convection currents will be formed in the space between the wall and the panel, or directly against the wall with an insulating plate between.

They can also be placed against the ceiling, at a minimum height of 10 ft. or suspended at some distance from the ceiling in the case of commercial or industrial buildings where appearance has not got to be taken into account.

Finally portable equipment of this type is also manufactured.

The temperature of the radiating surfaces is about 70° to 75° C. (158° to 167° F.).

Fig. 43 shows an isolated panel with brackets.

3° *High temperature electric radiant heating*

The « Hirae » panels are suitable for heating schools, large halls, churches, shops or workshops, where the air must be frequently renewed. They are also recommended in cases where heating is required at special points in buildings which are or are not already equipped with a general heating system. For example part of a workshop heated by a low temperature system in which clerks have to work. In this case they are a supplementary means of heating.

The panels are independent of the walls and ceiling. They are insulated on the back and only have one emitting surface.

They are sited horizontally, suspended from the ceiling, or at some distance from it, or vertically on brackets against the walls, or at an angle. In every case, the distance between the panels and the occupants of the room must be sufficient to make sure that no discomfort is caused. The angle of inclination must be chosen to give the maximum effect.

The temperature of the heating surface is of the order of 260° C. (500° F.).

Fig. 44 shows panels of this type fitted in a drawing office.

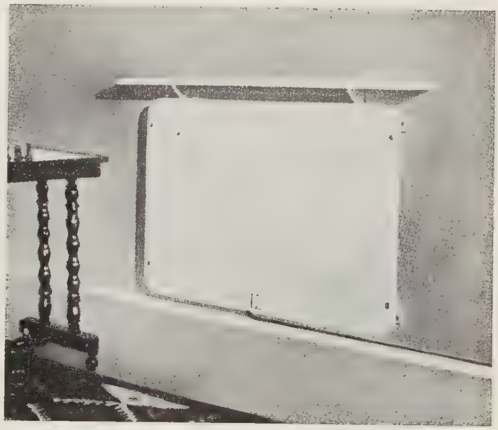


Fig. 43.

Remarks. — The technique of heating by radiation and by electricity is in course of being developed. Information and documents are coming forth in Great Britain, the United States and Belgium.

Trials are in hand to discover the best material for the panels by encasing the elements in various products : laminated wood, plastics, cement, asbestos, etc.

VI. — APPLICATION OF RADIANT HEATING TO ROLLING STOCK.

In this study which is addressed in the first place to railway technicians, we must mention the possibilities of applying radiant heating to the railway rolling stock.

It must be admitted that there are no records of any such applications having been made either in the United States or in Europe.

As far as we know, the great American Companies have not considered such applications. We do know, however that these Companies have equipped part of their passenger stock with air conditioning plant. They have followed in so doing the very marked tendencies of American technique in the field of heating and ventilating buildings.

We stressed at the end of our foreword the vogue for air conditioning in the United States, a vogue which is justified by the climatic conditions of the country which differ from European conditions.

For a long time already, most European railway companies have found themselves in such financial difficulties that they have had to slow down the evolution and the modernisation of their rolling stock.

In Great Britain, investigations appear to be in hand, made in conjunction with the railway technical services, and firms holding patents for radiant heating. These investigations deal with the use of steam and electricity.

In Belgium, the firm of Schréder has put forward certain proposals for test purposes.

We have had the opportunity of examining and testing panels supplied by an English firm to a firm in Brussels for tests to be carried out on tram platforms in

Fig. 44.

order to improve the working conditions of the drivers.

One of the panels was of laminated plywood, the other of plastic. When connected up with a supply of current these panels gave out a very gentle warmth, which could only be felt at a short distance.

One could think of using laminated plywood or plastic to mould the ceiling of carriages in such a manner as to obtain a large surface which would emit a sufficiently low temperature that would not inconvenience the passengers whose heads are necessarily close to the heating surface. There lies the chief difficulty, in our opinion.

The loss of heat from a vehicle travelling at high speed is considerable. A very extensive surface is then necessary to emit the required amount of heat without overheating the passenger's heads.

A combination of ceiling and wall heating might be used to obtain the large heating surface required.

It should be noted that the « Dulrae » panels described in the first paragraph of Chapter V (Low temperature electric radiant heating) could also be used.

In any case the steam heating solution now being investigated in Great Britain would be retained in the case of steam trains, without overlooking the possibility of using air as the heating fluid (see under Chapter III).

In the case of electric stock, electric heating would be used on account of the low cost of current.

It is already possible to heat the driving compartments of electric locomotives, as well as the locomotive itself. Radiant heating would do away with, or at least reduce to a considerable extent, the stirring up of the dust with the drawbacks that this entails for the equipment.

These optimistic views can be supported by mentioning the application of electric radiant heating with « Medrae » panels (see paragraph 3 of Chapter V) in the cabins of the steamer *Innisfallen* working between England and Ireland.

Owing to the favourable results obtained in this case, investigations are being made into the heating of sleeping car berths.

VII. — CONSIDERATIONS REGARDING THE RELATIVE PRICE OF RADIANT HEATING COMPARED WITH OTHER METHODS.

We have limited ourselves in this study to describing the various systems used in order to bring out their characteristics and advantages from the technical point of view.

We have not gone into the question of the necessary calculations, leaving it to the reader who wishes to go deeper into the subject to find out the relative facts in the literature which has already been published. In addition to the documents published by the firm of Crittall, we may mention the following works :

1. Radiant heating — A practical Treatise on American and European Practices in the desi-n and installation of Systems for Radiant Panel, or Infra-Red-Heating, Snow Melting and Radiant Cooling, including Step-by-Step Procedure, with Typical Problems Solved by the Application of Simplified Working Data, Charts and Tables, by T. Napier Adlam, Vice President, Sarco Mfg. Corp., and Consulting Engineer on Radiant Heating.

2. Chase Radiant Heating Manual, pu-

blished by the Chase Brass and Copper Co., Waterbury, 91, Connecticut.

3. Chase Radiant Heating Design Graphs, for use with Chase Radiant Heating Manual.

4. Chase Copper Tube for Radiant Heating.

For Railway technicians who read these notes, one question must inevitably come to mind :

« Are not the technical advantages put forward in favour of radiant heating obtained at the expense of additional costs, both as regards first cost and running expenses (consumption, maintenance, repairs)? In other words, does it not cost more, including sinking fund charges, than convection heating? » .

We will endeavour to answer this question, at least to some extent.

In calculating the running costs the following items must be taken into account :

1° First cost;

2° Running costs (fuel consumption, current, labour, etc.);

3° Maintenance and repair costs;

4° Capital depreciation.

A. — Panel installations fed by low pressure hot water.

This solution is mainly applicable to large buildings, such as offices, passenger stations, etc.

1. — *First cost.*

Generally speaking, it may be admitted that the cost of a radiant heat installation exceeds that of a convection heating system of the same capacity by 25 to 35 %.

It must not be forgotten that in addition to the installation costs, there is the cost of insulating to be carried out in the building. However when the main work is studied, taking into account the special conditions imposed by radiant heating, such costs can be considerably reduced. For example the choice of thick slabs for the ceilings makes it easier to install the coils and reduces the cost of insulation upwards or downwards as the case may be, according to whether ceiling or floor heating is being installed.

The use of thin ribbed slabs makes it harder to embed the coils and to insulate them.

On the credit side : with radiant heat installations there is, in most cases, no need to set up mechanical ventilation, the cost of which exceeds by far the difference between the cost of radiant heating and that of convection heating.

We have had occasion to examine the results of an investigation into the heating installation in a large block of administrative offices. The costs of radiant and convection heating were compared. The power of the installation was of the order of one million calories.

The cost of radiant heating exceeded that of convection heating by 24 %. Radiant heating was however adopted on account of the possibility of ventilating the offices whilst the staff were present, and the lower rate of capital depreciation.

We have seen figures which show that in certain cases radiant heating is less costly than convection heating.

This is the case in particular with churches. It should not surprise anyone who refers to the facts ascertained (quoted in Chapter II) when carrying out tests in

Liverpool cathedral. The moderate temperature (lower than that at ground level) of the higher parts of the building considerably reduced the loss of heat through walls and roof.

It is also the case with well designed heating installations for private houses and mansions, where the desire to hide the radiators leads in the first place to an increase in the heating surfaces required, and in the second place to expensive radiator covers.

2.— *Operating costs.*

Generally speaking there is a saving in fuel which varies from 10 % in the least favourable conditions to 25 %.

The other items, current and labour, are appreciably the same in both cases.

3. — *Maintenance and repair costs.*

As regards the furnace room, the costs are identical, though radiant heat is cheaper when the furnace works at a low temperature.

As regards the pipes, radiators, and taps required, obviously radiant heat is the more economical. Apart from the maintenance of the taps, there is no other expense. The paint work of the visible pipes and radiators has to be renewed from time to time. In addition with convection heating the paintwork, upholstery and hangings quickly get dirty owing to the dust it raises. There is no such drawback with radiant heat.

In passing we might quote the statement made by the medical officer in charge of a clinic in Paris during a visit we paid some twenty years ago to his premises. He told us that after radiant heat was installed in the operating theatre there was an extraordinary reduction in mortality after operations. Nothing had been changed except the system of heating; the staff and the equipment were the same as before. The only factor which could have led to this reduced mortality was the change in the heating system. He attributed this fortunate trend to the fact that there was no longer any movement of the dust and on the other hand to the better distribution of the heat.

4. — *Capital depreciation.*

Amortisation is generally calculated over 25 years in the case of convection heating installations.

Very often before this period has elapsed, the boilers have to be renewed in the case of thin cast iron or steel central heating boilers. In large installations where the use of boilers of an industrial type is possible, they only have to be renewed after much longer intervals, 40 or even 50 years.

With heating installations consisting of panels enclosing coils of pipes, a much longer period of amortisation is logical, since the pipes being encased in concrete cannot be affected in any way. We have seen calculations of capital depreciation based on a term of 50 years, which does not appear unreasonable in view of the guarantees offered by the way the fitting is carried out, the severe tests to which the coils are subjected, and the certainty that the pipes are protected.

5. — *Conclusions.*

Every technical engineer who draws up a working balance sheet, including

capital depreciation, knows that the item : « fuel » is the most important. A saving of 10 % usually is sufficient to make good the additional capital depreciation, even over the same period. If calculations are based on a longer period of amortisation for the radiant heat installation, the advantages of the latter method are even more obvious.

B. — Industrial installations with floor heating or by panels, above the heads of the workers, of the « Sunzway » or « Sunstrip » type (see Chapter II).

We have had no chance of comparing the cost of these solutions with the classical methods using air heaters or static surfaces.

However our experience of convection heating installations shows that the upper parts of the workshops are overheated, which leads to a considerable wastage of heat on account of the fact that in large shops a large proportion of the roof is glazed.

If on the other hand, the fact that radiant heat reduces the temperature of the upper parts is taken into account, it must follow that fuel consumption will be less in the case of radiant heat than with convection heating.

The reasons given under *A* above lead us to conclude that this saving in fuel consumption will make up for the possibly higher first cost when the complete balance sheet including amortisation is drawn up.

It must not be forgotten that radiant heat makes it possible to concentrate the heating in a large hall, or proportion of it, to suit the needs of each particular part.

C. — Gas and electrical installations.

We have no basis of comparison in the case of such installations.

The use of gas and electricity for heating must be limited to certain exceptional cases in view of the high cost of gas and electricity.

We are of the opinion however, that radiant heat using gas and electricity should lead to lower operating costs on account of the general characteristics of this method of heating which we have dealt with under *A* and *B* (reduced temperature in the upper parts, and possibility of directing the heat where it is required, or limiting it to certain well defined zones).

VIII. — CONCLUSIONS AND SUGGESTIONS FOR APPLICATIONS IN RAILWAY INSTALLATIONS.

Having described the various methods of radiant heat available, we wish to put forward suggestions for its application in railway installations.

We will deal with the different methods in the same order as above, and indicate possible applications for each method.

A. — Heating by low temperature radiant panels, fed by water at low pressure.

a) *Through the ceiling.*

Offices. — The use of radiant heat makes it possible to renew the air, by opening the windows when required or keeping them open all the time, without inconveniencing the occupiers. It is possible to avoid the cost of mechanical ventilation in this way.

In the case of offices in very sunny positions, it is possible to reduce the temperature in summer by running cold water through the pipes.

We are not in favour of floor heating, as permanent contact with an even slightly warm floor may inconvenience sedentary staff. It should be remembered that with ceiling heating, part of the warmth reaches through to the floor above, so that the floor in the office above will be slightly warm, but not to an extent that will cause any discomfort. On the contrary it increases the comfort, and makes it possible to have paved floors.

Waiting rooms. — The walls of waiting rooms are generally provided with benches, which makes it necessary to site the radiators behind the benches or underneath them. Experience has proved that maintenance is difficult and the radiator recesses quickly become full of dust.

Signal boxes. — The loss of heat from signal boxes is enormous; it means that radiators must be of considerable size and take up a lot of room; and since the window sills are very near the ground, only the lowest types of radiators can be used.

Windows frequently have to be opened in the signal boxes. With radiator heating, there is an appreciable loss of heat in this way, which has to be allowed for in making the calculations. Ceiling heating makes it possible to keep the windows open without making it uncomfortable for the signalmen.

Though it is difficult to heat signal boxes properly, it is even harder to protect them against excessive heat in the summer. The presence of panels in the ceiling would make it possible to cool them by circulating cold water.

b) *Floor heating.*

Entrance halls in stations. — It has been found that the radiators attract passengers and sometimes idle people who like to congregate around them. This can impede circulation and the proper working of the installations.

Floor heating is rational in such cases since it warms the passenger's feet while their bodies are already well protected by warm clothes.

Passages leading to the platforms. — In important stations the heating of these passages would increase the comfort of passengers exposed to draughts.

Waiting rooms on platforms. — The siting of radiators is difficult, since there are benches all round the walls. Floor heating is justified for the same reasons as those put forward in the case of the entrance halls.

Passenger platforms. — The heating of certain parts of the platforms, especially on through stations, might be considered.

Shops. — When the water and electricity mains have been well sited and the layout of the shop carefully planned, especially the arrangement of the gangways and lines of machine tools, floor heating can be considered. The workers in front of the machines will find it comfortable to be in contact with a slightly warmed floor.

c) *Through the walls.*

The use of heating through the walls can only be considered in the case of

places whose use is not likely to be altered, such as waiting rooms. It must be certain that the walls will remain free without any furniture being placed against them, which would impede radiation. Care must also be taken that the panels are not sited in places accessible to passengers, for example the lower part of the walls, where passengers might collect and stand,

B. — Panels fed directly by steam or superheated water.

a) *Sunzway type panels (pipe welded between two metal plates).* (See Fig. 23 to 27.)

Shops. — Such panels can be used with advantage to heat shops with plain walls, pillars or metal columns to which the panels can be fastened.

Fig. 26 shows that the radius of action of these panels, which is about 15 m. (49' 2 1/2''), makes it possible to heat very large halls. They can not only assure the general heating of all the hall, but also heat part of the hall.

They can be used with advantage in machine tool shops, assembly or boiler shops. Their use is indicated in the case of localised heating of such places as hangars, stores, etc.

Railcar sheds. — The heating of railcar sheds by the use of radiant panels is possible in spite of the renewal of the air made necessary by the evacuation of exhaust gases from the motors.

By a careful choice of the siting and angle of inclination of the panels, the railcars can be heated and the workers kept warm, not only at floor level but also in the inspection pits.

Locomotive sheds. — The heating of locomotive sheds is a very difficult matter on account of the frequent or permanent opening of the doors, and because the air must be renewed owing to the evacuation of smoke.

In practice locomotive sheds are only warmed by braziers during very cold periods, to prevent frost damage. Working conditions are therefore very uncomfortable for the men.

Radiant panels fed by steam or superheated water could be used in such parts of the shed which are particularly exposed to the cold ; i. e. : where locomotives are kept when the fires are out, and in those parts where the workers have to carry out any lengthy jobs.

To prevent the panels from getting rusty, the connections might be planned so as to allow the panels to be removed when not in use.

b) *Sunstrip type panels, pipes inserted in an insulated plate.* (See Figs. 28 and 29.)

Extensive halls of no great height. — Sunstrip panels are completely clear of the walls and pillars. They could be used in large machine tool shops, garages, stores and depots which are heated throughout or only in places.

Transhipment platforms. — There are no side walls on some of these platforms. Heating panels cannot be installed in the floor since vehicles run over it, or it is cluttered up with parcels.

Sunstrip panels hung from the roof would make working conditions more comfortable.

Goods sheds. — The general heating of goods sheds is not usually necessary.

On the other hand, the heating of those parts in which the work is concentrated could be economically effected by means of suspended panels.

Station platforms. — Suspended panels under the roofs would appreciably increase the comfort of passengers who are obliged to wait for trains.

C. — Heating by warming the floors by circulating hot air.

Applications of this method could only be considered in very limited cases. The use of the premises must be definitely decided upon so that no subsequent changes are likely. (See cases mentioned in the report : Liverpool Cathedral, hospital buildings.)

The only place in which we can see that it would find a useful application would be the entrance halls of stations.

However in the case of complete heating installations by hot air, such as the maritime station at Cherbourg, it might be possible to heat large halls through the floor in this way.

D. — Radiant heating by gas.
(See Figs. 31 to 34.)

Small shops. — When no boilers are available, gas heating might be considered. This would be particularly useful when only some part of the shop needs to be warmed, for example a forge part of which is occupied by machine tools.

Station platforms. — Under the platform roofs when no boiler is included in the station equipment.

If lighted up when the platform is open to the public and shut down as soon as it is closed, running costs would be reduced to the minimum. Intermittent heating would be possible without any fear of damage by frost.

E. — Radiant heating by electricity.

The high cost of electricity is an obstacle to the extended use of this method of heating. It would be possible in the case of installations equipped with high-tension stations supplying current at low cost. The choice of the type of panel, at low, medium or high temperature, would depend upon the nature of the place to be heated. We are only contemplating local heating therefore limited to certain special cases.

a) *Low temperature radiant heat.*
(See Figs. 40, 41 and 42.)

Offices. — In substations or transformer stations without central heating. Also in dispatching offices and telephone exchanges in which the question of cleanliness and absence of dust justifies the extra cost of electric heating.

Dispensaries. — Such places, which are only occupied at certain times, and where cleanliness is an essential need, can be heated in this way. When the heating panels are divided up between the ceiling and the walls, a very regular and uniform heat can be obtained.

b) *Medium temperature radiant heat.*
(Fig. 43.)

Small shops near the installations mentioned above.

Clinics. — General heating of the premises, especially the operating theatre, as a supplement to the low temperature heating, in order to be able to raise the temperature as required in cases of urgency

c) *Radiant heat at high temperature.*

Shops. — Applications to larger areas than those considered under *A* and *B* above, for example the whole substation.

Temporary installations. — For example to heat a drawing office such as that shown in Fig. 44.

Whenever electrical heating is used, it is necessary to fit thermostats, in order to reduce the consumption of current as much as possible.

Fig. 45.

F. — Applications of radiant heat to rolling stock.

Such applications being in the experimental stage only, the reader is referred to the information given in the relevant chapter of the article.

G. — Protection of track equipment against snow.

Finally we might mention an application of ground level heating which is not an example of radiant heat but of heating by conductibility. (Fig. 45.)

In this case coils are embedded in a concrete layer around the track equipment to be protected against snow. Applications of this type have been made in the United States not only near railway stations, but on much larger areas such as aerodrome runways.

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We should be very glad if readers of this report who have had occasion to make use of radiant heating under any form would communicate the results obtained to us.

(Translated from French.)

[621 .335 (439)]

GANZ-KANDO system single phase 50 cycle locomotives, under construction for the Hungarian State Railways,

by L. KULLMANN.

Engineer, Deputy Chief of the Electrical Section of the Hungarian State Railways.

The electrification of the main line Budapest-Hegyeshalom (190 route km. [118 miles] - 640 km. [398 miles] of track) by the Hungarian State Railways was commenced in 1931 and completed in 1934.

The electric traction used on this line is the single phase 50 cycle system. The overhead conductor is fed at 16 kV by substations with single phase transformers connected to the three phase 110 kV national network. The locomotives have been built according to the Kando System with a phase converter driven by a single phase induction traction motor. (1)

The favourable results obtained during the past 16 years on this line has led the Hungarian State Railways to extend this system of electrification to their other main lines. Investigation with a view to modernising fixed plant and rolling stock has commenced. With the stationary plant it has been only possible to improve minor details.

In the design of the new locomotives, whilst retaining the good features of the first Kando type engines, improved results have been obtained equivalent to those of the most modern electric locomotives built in foreign countries, viz. a specific weight comparable to that of locomotives fed at 16.2/3rds cycles and a reduction in maintenance costs to the level of those found with direct current or at 16.2/3rds cycles.

Two locomotives are now being constructed at Ganz electric works, and in the Forge, Steel Works and Building Works of the Hungarian State, which have the following characteristics :

Arrangement of axles	Bo' Co'				
Load per axle	17 metric tons (16.731 Engl.t.)				
Weight in working order	85 metric tons (83.657 Engl.t.)				
Diameter of wheels	1 040 mm. (3′ 4 15/16″)				
Total length	14 600 mm. (47′ 10 5/8″)				
Maximum speed	125 km/h. (77 miles p. h.)				
Speed in km./h.	25	50	75	100	125
Speed in miles p. h.	(15)	(31)	(46)	(62)	(77)
Tractive effort of short time rating in kgr.	21 000	21 000	16 000	12 000	9 600
Tractive effort of short time rating in lbs.	(46 300)	(46 300)	(35 273)	(26 455)	(21 164)
1 hour rating tractive effort in kgr.. . .	13 500	13 500	10 800	8 600	6 900
1 hour rating tractive effort in lbs. . .	(29 762)	(29 762)	(23 810)	(18 960)	(15 212)
1 hour rating capacities in H. P. measures at the rim	1 250	2 500	3 000	3 200	3 200

(1) See : *Elektrische Bahnen*, 1932-II and 1934-IV. *Ganz Review*, 1932, International Conference of Railway Administrations, using high tension, Session 1933, No. 18.

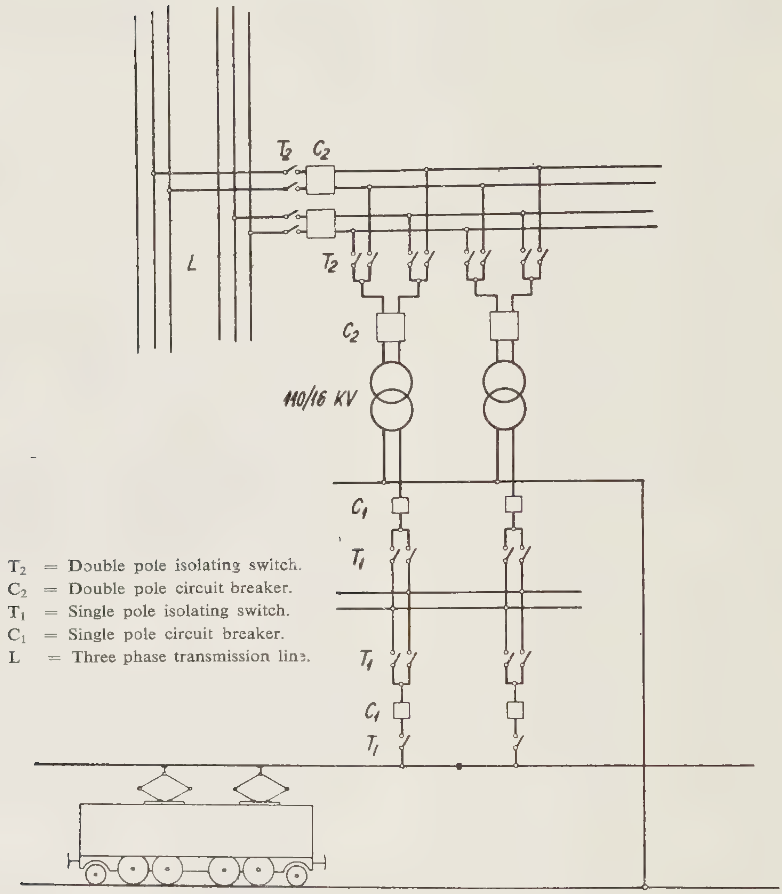


Fig. 1. — Diagram of the principal circuits of the single phase 50 cycle sub-stations.

The locomotives are fitted with a phase converter and a frequency converter fitted on a common shaft. The current is brought in the first place to the phase converter; the traction motors (induction type with slip rings), are fed by a secondary winding on the frequency converter, the three phase frequency current being variable viz. 25, 50, 75, 100, and 125 cycles.

The frequency converter is a simple induction machine which can be changed for 2,4 or 6 poles respectively. It has a constant speed of 1 500 r. p. m. The characteristics of the frequency converter at the different notches are as follows :—

Speed km./h.	25	50	75	100	125
No. of poles of the frequency converter	2	—	2	4	6
The frequency converter is fed on the . . .	stator	—		rotor	
Rotary direction of the field of the frequency converter in relation to the rotary direction of the phase converter	identical	—		identical	
Frequency attained	25	50	75	100	125

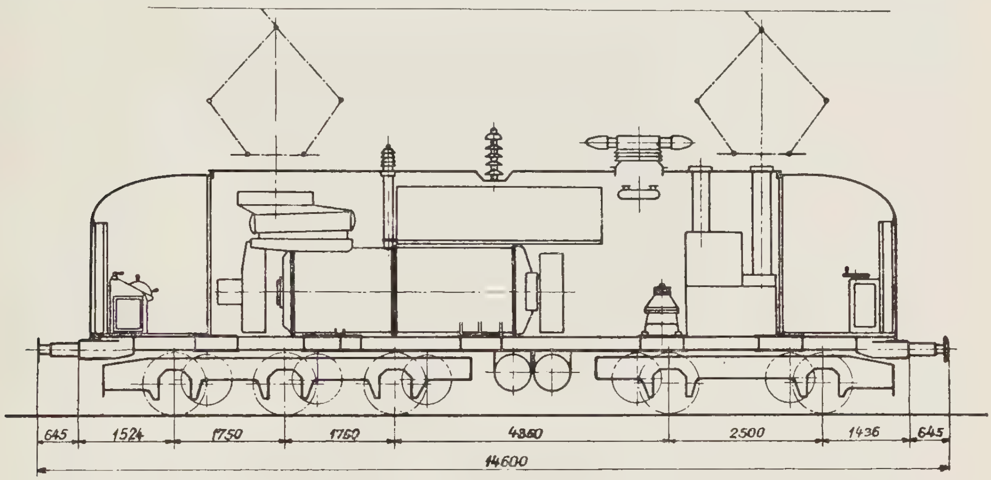


Fig. 2.

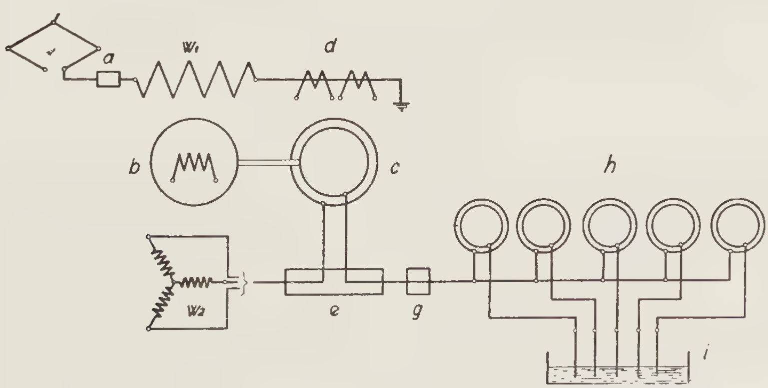


Fig. 3. — Simplified diagram of the principal circuits of the Bo' Co' locomotive.

a	=	Main switch.
b	=	Phase converter.
c	=	Frequency converter.
d	=	Measuring transformer.
e	=	Switch gear.
g	=	Reversing switch.
h	=	Traction motors.
i	=	Liquid starter.
W_1	=	Primary winding of the phase converter.
W_2	=	Secondary winding of the phase converter.

The starting of the locomotive is carried out by means of liquid rheostat inserted in the secondary circuit of the traction motors. The operation of the rheostat, and by that the power absorbed by the locomotive, is carried out by an automatic control equipment. The excitation of the phase converter is also automatically controlled according to the power absorbed by the locomotive.

The phase converter is excited from the line and also augmented by a winding, according to the primary power absorbed. One of the advantages resulting from the use of the phase converter is that power factor of energy of the overhead conductor line is equal to unity. The maintenance of the converters presents no difficulties; they are overhauled every 450 000 km. (280 000 miles). The locomotives are built so that when coupled together they can be driven from one driving cab.

The connections between the phase converter, the frequency converter and the motors are by means of electro-pneumatic contactors.

The ventilators and pumps for cooling the electric motors are, for the most part, worked directly by the shaft of the phase and frequency converters. The auxiliaries are fed by separate motors which are induction motors with squirrel cages.

The mechanical portion of the locomotive consists of the following: the body, resting on one 4-wheeled and one 6-weeled bogie. The displacement of the bogies in relation to the body is made possible by means of the Ronai mechanism. This

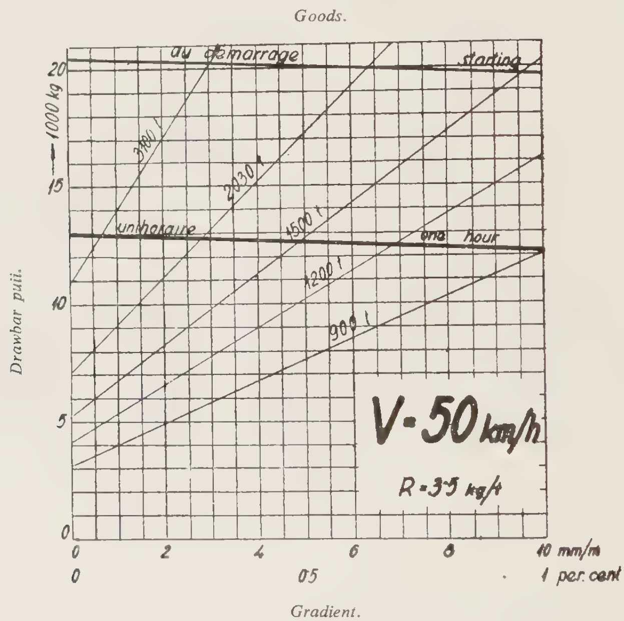


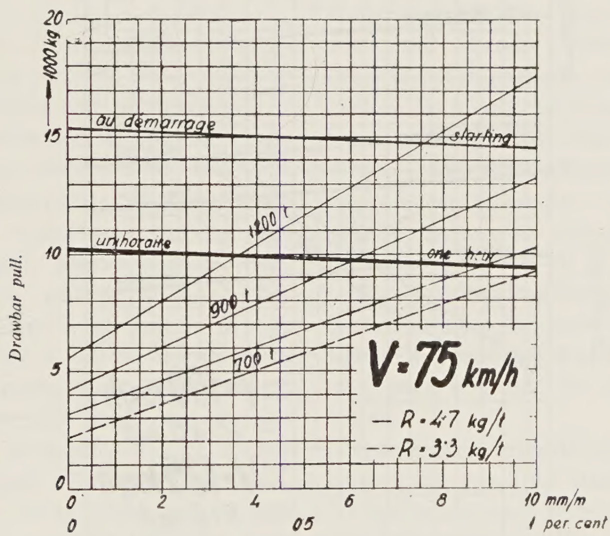
Fig. 4.

eliminates the pivoting system at the bogie centre. The body rests at four points on the solebars of the bogie frame. Two of the four bearing points merely support the body, the other two guiding the bogie. This arrangement has been used, for the past 8 years, on vehicles constructed for the Hungarian State Railways.

tion of weight, the type of construction adopted is that of bogies with a body, the roof and walls of which form part of the transmission of efforts.

The Ronai construction also plays an important part in the reduction of weight of the underframe. By this means the weight of the body is transmitted directly

Passenger & freight.



Gradient.

Fig. 5.

—— 4-wheeled wagon.

— — 8-wheeled wagon.

The bogie frame is suspended on the axles by means of balancers and spiral springs. The balancers not only equalise the weight of the vehicles, but also transmit the tractive effort. It is with this arrangement that the best adhesion can be obtained.

Roller bearing axleboxes have been fitted. Each axle is fitted with a single gear.

In order to obtain the maximum reduc-

to the axles in the plane of the bogie frame solebars and in consequence and owing to the pivot arrangement being eliminated, the length and the weight of the bogie frames can be reduced to a minimum. With a bogie having three motors, this is particularly noticeable.

A further reduction of weight is obtained by the use of three phase high speed traction motors (2 500 r.p.m. at 125 km/h.

[77 m.p.h.]). The weight is approximately 1 800 kgr. and the hourly rating 640 H.P.

The small size of the motor and the light load per axle (17 Metric tons [16.731 Engl. t.]) has enabled nose suspension to be used. This system is especially useful in the present instance owing to the fact that the motor has no commutator but only slip rings, that there are no commutation troubles caused by inequalities of track.

An appreciable reduction in maintenance costs can be expected owing to the adoption of individual control of axles and the reduction in the number of details subjected to wear or needing periodical lubrication.

The regenerative braking which can be started up without any additional installation also reduces maintenance costs.

The fact that each running step corresponds to a constant predetermined speed enables schedules to be kept accurately and another contributary factor is the entirely automatic control of the locomotive. When starting the driver places the lever in the chosen speed notch and adjusts the power required for acceleration. So long as adjusted speed requires no alteration, the driver has nothing further to do. The power absorbed by the locomotive adjusts itself automatically to that required by the conditions of the track.

The locomotive described above can haul at a constant speed goods trains and

Passenger trains.

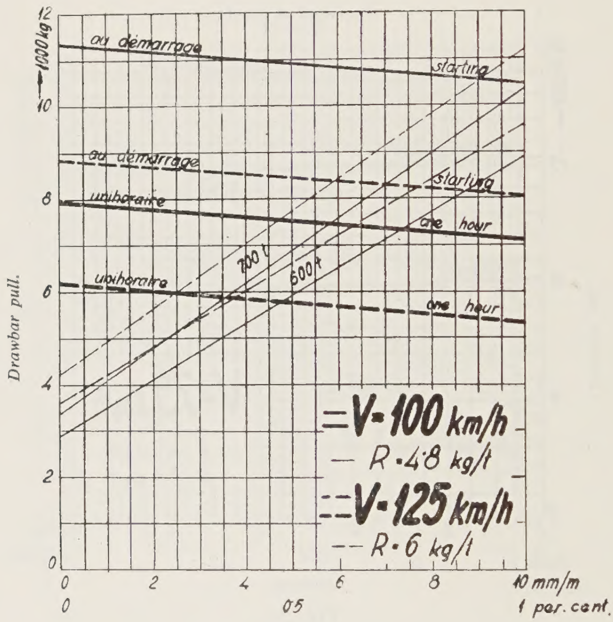


Fig. 6.

slow and express passenger trains. The Hungarian State Railways propose using for future electrification, this type only, as they are the ideal mixed traffic locomotives.

In examining more closely the tractive effort mentioned above, it can be stated that locomotives with the phase converter have sufficient overcharged overload capacity for short duration above the hourly rating at all speed notches including the maximum.

It is well known, however, that for locomotives on direct current the maximum tractive effort which can be developed is limited by the reduction of the maximum field, and for locomotives of 16.2/3rds cycles by the characteristic effort so determined by the transformer giving the maximum voltage. Direct current locomotives therefore, only produce higher speeds that exceed a minimum of the tractive effort for a short duration in relation to the hourly effort, this being nil at maximum speed, these locomotives being incapable of developing the hourly effort at this speed. On the other hand, for locomotives of 16.2/3rds cycles this exceeding of the tractive effort for short duration ceases very quickly above the speed corresponding to the hourly maximum power. In addition these locomotives are not generally capable of developing their maximum hourly power except at a reduced speed, above this speed the power lessens. With the Ganz-Kando system locomotives, however, the hourly maximum power can be used at the maximum speed and even then the locomotive can be overloaded above the hourly power, which applies to the new locomotives now under construction.

It is also necessary to take into consideration that direct current in relation to 16.2/3rds cycle locomotives show interruption in the hourly effort curve of the diagram « traction-speed to effort » due to the coupling of the respective motors in series, series parallel and parallel.

Economic running is not possible with these locomotives except within the limits fixed by the hourly effort curves mentioned above, and definite speeds according to the characteristics of the motor without starting resistance. On the other hand, with the Kando system locomotives, economical running is automatically carried out at a constant speed irrespective of the weight of the train, whereas with direct current locomotives, the speed depends on the weight of the train, which makes running to schedules much more difficult.

The proposed schedules of the Ganz Kando system locomotives are shown in figures 4, 5 and 6 worked out on the basis of constant speeds for different types of trains.

It has been calculated that through the economies resulting from electrifying at 50 cycles the main lines around Budapest, on which there is traffic of 4.5 to 7 million of tonnes-km. gross, per annum and per km.; the first cost will be liquidated in about 15 years. Such a result could not be counted upon with any other system of electrification.

The Hungarian State Railways believe that the new locomotives now being constructed will satisfactorily meet all modern requirements in the electrification of lines with the single phase system of 50 cycles. Trials carried out by the French National Railways of traction at 50 cycles have been followed with great interest and they will contribute to the development of the electrification in Hungary.